1 INTRODUCTION

Since the end of World War II, development of larger, more complex systems has increased awareness of, and need for, System Engineering (SE). The principles of SE were especially significant in the development of ballistic missile weapon systems because of the need to apply new technology to both the system's existing and new parts while controlling the inherent risks. Difficulties experienced in the evolution of the integrated designs of new systems (especially in the software community) have led to the development of specific methods and techniques within the SE discipline in an attempt to provide better insight to and control of the development and management process. Commercial applications of SE have also expanded and are being used by utility companies, aviation, the automobile industry, the computer industry, communications, and health care.

There are many definitions of SE in books, professional journals, and classrooms. The definition arrived at by Simon Ramo, one of the early developers of formal SE and the "R" in TRW, is used by the System Engineering Manual (SEM):

> *A discipline that concentrates on the design and application of the whole (system) as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables and relating the social to the technical aspect.*

Because of lessons learned within the government and industry, the Federal Aviation Administration (FAA) is pursuing SE concepts. This manual reflects the application of SE within the FAA. The FAA's SE applies both technical and management principles in a manner that:

- Results in a responsive system design from an operational need through the use of a structured, iterative process
- Integrates the contributions of both traditional engineering and specialty disciplines to meet cost, technical, quality, and schedule objectives
- Provides a product that satisfies all stakeholders

The three primary purposes of this manual are to:

- Define the FAA's integrated practice of SE, which is compatible with all components of the agency and consistent with sound government and industry best practice, to be employed by any engineer or group performing a task requiring an SE approach
- Provide methods and tools that result in effective and consistent SE
- Supply detailed information on work products of SE activities that are needed to ensure uniform and consistent high-quality products

1.1 Scope

The SEM describes the proper application of SE elements within the FAA. These SE elements are specifically designed for the acquisition of systems for the National Airspace System (NAS) in the context of the FAA Acquisition Management System (AMS). However, SE is one of the key practices of the FAA, and the elements discussed here can be applied in a number of other FAA functions beyond acquisition. "Perform System Engineering" is specifically part of the AMS and is tightly linked with other AMS processes.

SE provides a comprehensive, structured, and disciplined approach for new system product and process developments, upgrades, modifications, and engineering efforts conducted to resolve problems in fielded systems in all development, production, and operations/support phases. SE is applicable to technical efforts that support advanced development of new technologies and their application. It applies to large- and small-scale systems (ranging in size and complexity from the NAS to individual parts such as bolts or wire bundles), single or multiple procurements, and replacement of current products and processes. The process is applicable to systems regardless of composition, including those that are integrated from diverse elements, either hardware-intensive or software-intensive. SE involves design and management of a total system, including hardware and software as well as other system elements. Each shall be considered in analyses, trade studies, and engineering methodology.

The SEM is designed as a how-to manual or guide to SE and defines the constituent SE elements to be performed throughout the program lifecycle. When the term "program" is used, it is intended to mean projects at all levels of size and complexity, ranging from the NAS to individual parts. While the SEM is primarily directed at NAS modernization, individual programs shall tailor the application of processes, tools, and techniques according to program requirements, with implementation of these processes directed by the appropriate SE management authority designated in the NAS System Engineering Management Plan (SEMP) or, on a given program, by the Program Manager or Chief System Engineer. This manual includes guidance on tailoring.

Figure 1.1-1 is a high-level overview of the organizational levels involved in SE along with several key SE work products. This figure provides only a contextual overview of SE within the FAA. Specific details on who is doing what regarding SE are explained in an organization or program SEMP.

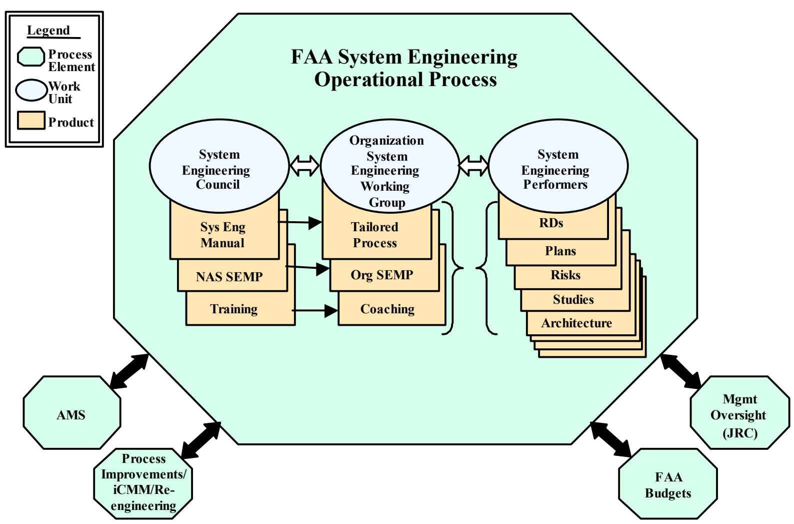


Figure 1.1-1. Federal Aviation Administration System Engineering Operational Process

1.2 Purpose

The SEM and SEMP are designed to work together. The SEM answers SE questions related to what and how, while the SEMP answers SE questions related to what, who, when, and why (i.e., why a particular organization or program is implementing or not implementing a particular SE element versus the SEM's discussion on a SE element's purpose). They are directly connected by the "what" or products and activities of SE. This relationship between the SEM and SEMP appears in Figure 1.2-1.

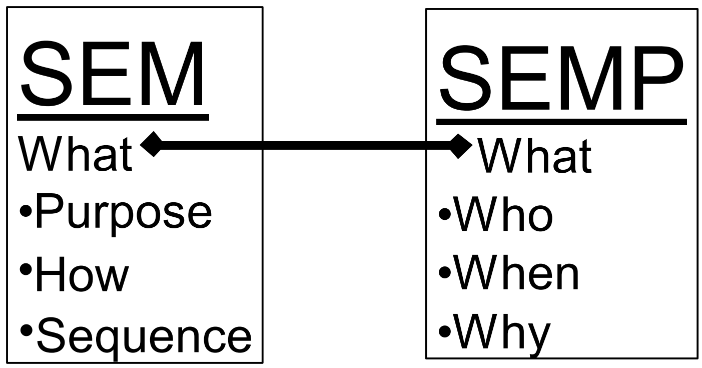


Figure 1.2-1. Relationship Between the System Engineering Manual and the System Engineering Management Plan

The SEM describes the key process activities and products that are necessary to effectively implement SE principles. The manual offers both what-to-do and how-to-do-it information for the elements defined for the FAA's SE model. These SE elements appear in Figure 1.2-2.

The SEM describes the purpose of specific SE activities, as well as guidance for determining the sequence in which each activity is to be performed relative to the AMS phases. The SE activities are applicable to most engineering programs. Program cost/benefit considerations shall be the basis for the allocation of appropriate resources, including manpower and schedule, to any process activity.

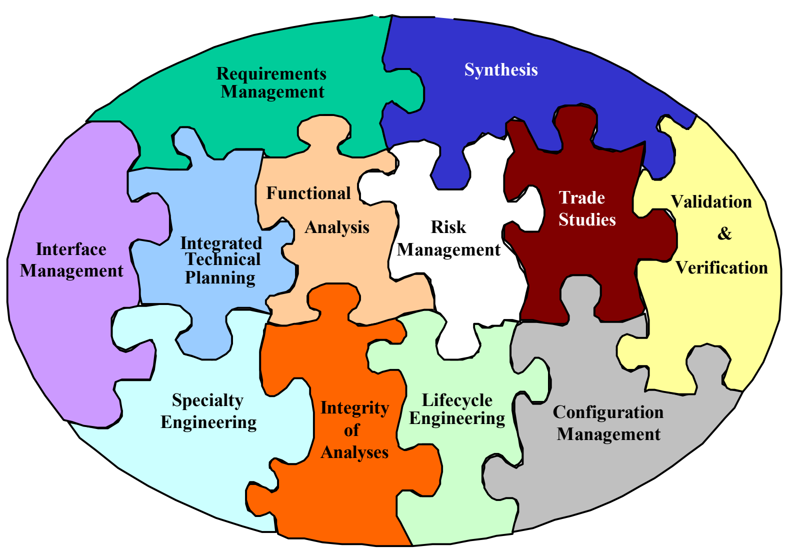


Figure 1.2-2. Federal Aviation Administration System Engineering Elements

The process descriptions consist of all aspects of each SE process, including the need to design for safety, as well as for affordability, performance, usability, operational suitability, and cost of ownership. On some programs, a given activity may be performed informally (e.g., in an engineer's notebook) or formally, with interim products under formal baseline control.

The SEM defines the SE elements, as conducted in the FAA, along with the work products generated from each SE elements. The SE elements are listed in Table 1.2-1:

Table 1.2-1. System Engineering Elements

System Engineering Element	Purpose of Element
Integrated Technical Planning	Plans the SE efforts and products.
Requirements Management	Identifies and manages the requirements that describe the desired characteristics of the system.
Functional Analysis	Describes the functional characteristics (what the system needs to do) that are used to derive requirements.
Synthesis	Transforms requirements into physical solutions.
Trade Studies	Assists decisionmaking by analyzing and selecting the best-balanced solutions to requirements.
Interface Management	Identifies and manages the interactions between segments within a system or interactions with other peer systems.
Specialty Engineering	Analyzes the system, requirements, functions, solutions, and/or interfaces using specialized skills and tools. Assists in the derivation of requirements, synthesis of solutions, selection of alternatives, and validation and verification of requirements.
Integrity of Analyses	Ensures that the analyses provide the required level of fidelity and accuracy.
Risk Management	Identifies, analyzes, and manages the uncertainties of achieving program requirements by developing strategies to reduce the severity or likelihood of those uncertainties.
Configuration Management	Establishes and maintains consistency and manages change in the system performance, functional, and physical attributes.
Validation and Verification	Determines if system requirements are correct. Determines that the solution meets the validated requirements.
Lifecycle Engineering	Identifies and manages requirements for system lifecycle attributes including real estate management, deployment and transition, integrated logistics support,

System Engineering Element	Purpose of Element
	sustainment/technology evolution, and disposal.
System Engineering Process Management	Manages and maintains SE processes to meet FAA goals. Gains agency-wide skill and standardization by continuously improving the effectiveness and efficiency of SE processes and tools.

Each program shall determine which SE elements and products are applicable to its success. A program shall justify its "tailoring out" of specific SE elements and products that are not deemed necessary. This tailoring and associated justification shall be captured in appropriate planning documents. The appropriate degree of tailoring for any SE process activity and its product(s) is determined by:

- Stakeholder needs
- Level of complexity of the program
- Need for communication of what activity is being performed (across members of a program team, across organizations, and/or over time to support future activities)
- Level of risk that is acceptable within the program

1.3 System Engineering Management Organization

SE addresses the translation of stakeholder needs into system requirements and facilitates the process by which the specification of systems and/or components satisfies those requirements. Although programs differ in underlying requirements, SE provides a logical sequence of steps toward the derivation of good requirements and the transformation into solutions regardless of the program's size or complexity. These steps generate a series of work products that specify characteristics of systems (at any level), demonstrate and document the traceability to stakeholder needs (expressed or implied), and define how the requirements are validated and the systems (and associated components) are verified. To maximize effectiveness, SE commences before any significant product development activities and continues throughout the program's lifecycle. If performed correctly, SE helps to ensure that program execution is right from the start and that if problems are encountered, they are detected and resolved early, which reduces program cost and risk as shown in Figure 1.3-1.

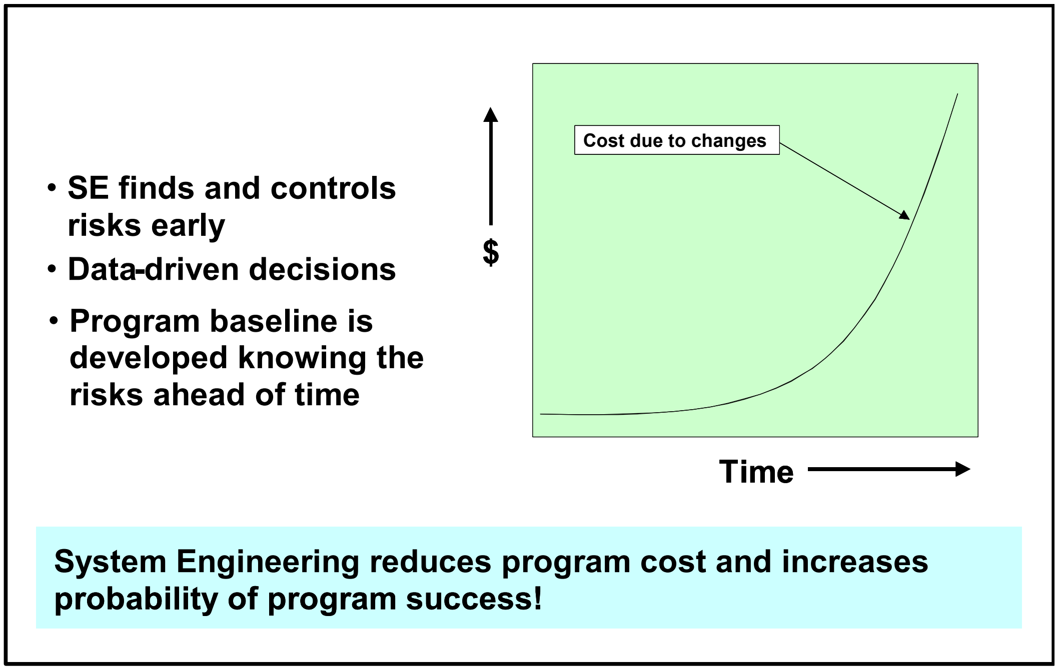


Figure 1.3-1. Benefits of System Engineering

1.3.1 Process-Based Management and System Engineering

The process flow for the "Perform System Engineering Process" appears in Figure 1.3-2. This model is a top-level process model that does not reflect all interactions among the SE processes. The details of these element interactions are discussed in Chapters 3 and 4. SE applies to all product development activities and is used throughout the program's lifecycle. This model shows the 12 lower-level processes and the 13th overarching process management element (the shaded blocks) that make up FAA SE. (The Validation and Verification process is depicted twice in the model but is considered one process.) Note that the figure does not show the iterative nature of SE by which each of the processes may be repeated multiple times throughout product development and program lifecycles at each level of system decomposition. It is the systematic iteration through these processes that leads to success. Throughout the manual, there are references to the FAA integrated Capability Maturity Model (iCMM) process areas and base processes. These references assist the user in complying with audits that are performed in support of iCMM.

SE provides key inputs to determining a solution as part of the Investment Analysis (IA) and Solution Implementation (SI) lifecycle phases. SE is initiated by the identification of a need (capability shortfall) in the existing system. This need drives the generation of a mission need statement (MNS). The SE outputs are used for subsequent iterations and provide the full set of requirements for the system being developed.

The Shaded Blocks Represent the Process Steps for "System Engineering"

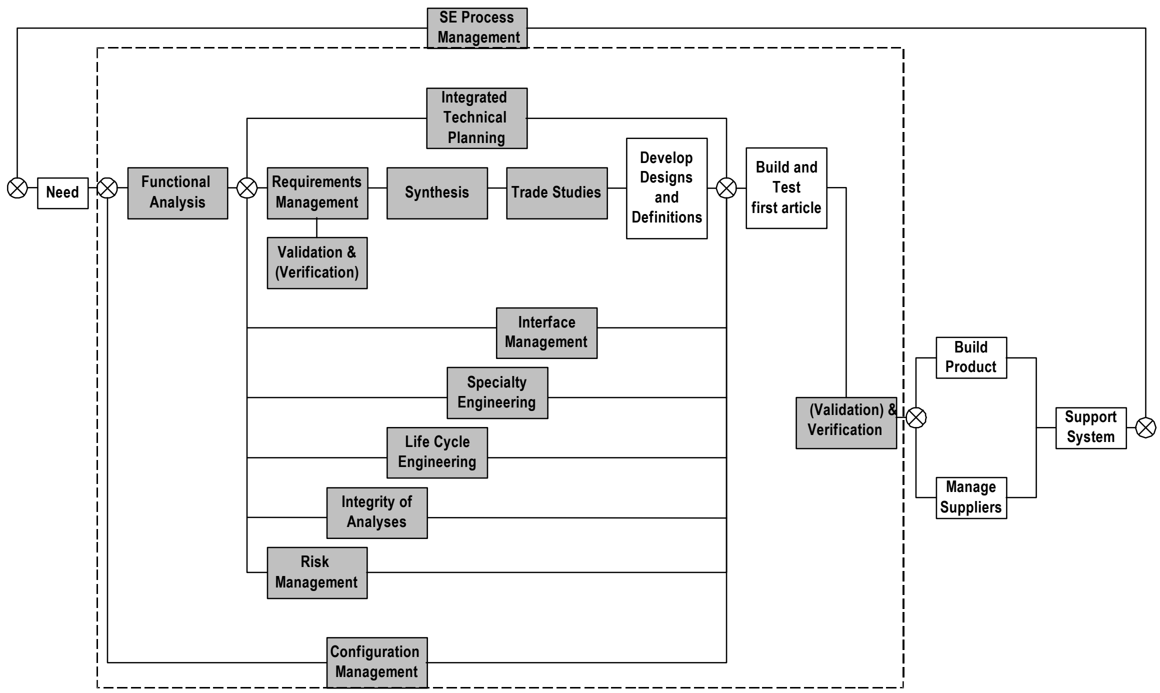


Figure 1.3-2. Perform System Engineering Process Model

1.3.2 System Engineering Process Descriptions

The SE process descriptions in Chapter 4 include the following information:

- **Process Definition.** Included are the purpose for carrying out the specific SE process and a narrative description of the specific SE process. This narrative discusses the function for the process (what to do). Program implementers may use this information to tailor specific activities to align with the development events of the program.
- **Process-Based Management (PBM) Charts.** Each SE element section in Chapter 4 contains a standard template that uses PBM charts to describe the SE element process. The templates indicate the major steps of the SE process, inputs to the process and associated providers, possible outputs generated, and associated product customers (from an SE view). The SEM also identifies the supplying (inputs) and using (outputs) processes that are used during process implementation to establish necessary program communication, documentation, and review activities.

Each SE process is broken down into its major workflow tasks, which are also shown in PBM chart form.

- **How To Do It.** The SEM discusses specific approaches or techniques that are used to implement each SE process and provides guidance for selecting the right approach for a given program phase. It summarizes the key points, focusing on the what and why, as well as the how.
- **Inputs.** This category includes information from external sources or from other processes that is received during the conduct of the process or that initiates the process.
- **Outputs.** This category includes information developed during and by the conduct of the process.
- **Entrance Criteria.** This category is what is required to start the process.

- **Exit Criteria.** This category includes activities that are performed when the process is complete.
- **Metrics.** This category includes examples of metrics that may be used to measure the level of performance for the process, as well as the work products generated by the process.
- **Methods/Tools.** This category includes specific tools or methods that are necessary (or desirable) to efficiently implement the process as described. They also guide the user as to what is available within the AMS FAA Acquisition System Toolset (FAST) (http://fast.faa.gov/).
- **Examples.** This category includes examples of SE work products as well as standard templates for producing the various SE work products. Examples may be contained either within a particular section of Chapter 4, an appendix to the SEM, or on the FAA's intranet, in which case a reference uniform resource locator (URL) will be provided.
- **References.** This category includes documents from the government, industry, and academia that cover relevant topics regarding that section.

2 OVERVIEW OF SYSTEM ENGINEERING

This section traces several key developments and lessons learned that led to today's championing of SE as a powerful approach to organizing and conducting complex programs, such as those found in the NAS. SE continues to evolve, with an emphasis on stronger commercial- and team-based engineering organizations, as well as organizations without technical products. Before World War II, architects and civil engineers were, in effect, system engineers who worked on large, primarily civil, engineering projects, including the Egyptian pyramids, Roman aqueducts, Hoover Dam, the Golden Gate Bridge, and the Empire State Building, while other architects worked on trains and large ships. However, "early" system engineers operated without any theory or science to support SE. Thus, they lacked defined and consistently applied processes or practices. During World War II, a program manager and chief engineer might oversee development of an aircraft program, while others managed key subsystems, such as propulsion, controls, structure, and support systems, leading to a lack of uniformity throughout the process.

Some additional SE elements, such as operations research and decision analysis, gained prominence during and after World War II. Today, with more complex requirements and systems, chief engineers use SE to develop requirements and to integrate the activities of the program teams.

SE began to evolve as a branch of engineering during the late 1950s. At this time—when both the race to space and the race to develop missiles equipped with nuclear warheads were considered absolutely essential for national survival—the military services and their civilian contractors were under extreme pressure to develop, test, and place in operation nuclear-tipped missiles and orbiting satellites. In this climate, the services and their contractors sought tools and techniques to improve system performance (mission success) and program management (technical performance, delivery schedule, and cost control). Engineering management evolved, standardizing the use of specifications, interface documents, design reviews, and formal configuration management. The advent of hybrid and digital computers permitted extensive simulation and evaluation of systems, subsystems, and components that facilitated accurate synthesis and tradeoff of system elements.

The lessons learned with development programs led to innovative practices in all phases of high-technology product development. A driving force for these innovations was attainment of high-system reliability. Some examples of changes introduced during the period are:

- Parts traceability
- Materials and process control
- Change control
- Product accountability
- Formal interface control
- Requirements traceability

2.1 What Is System Engineering?

Beyond the definition used in the "Introduction" (Chapter 1), SE is an overarching process that trades off and integrates elements within a system's design to achieve the best overall product and/or capability known as a system. Although there are some important aspects of program management in SE, it is still much more of an engineering discipline than a management discipline. SE requires quantitative and qualitative decisionmaking involving tradeoffs, optimization, selection, and integration of the results from many engineering disciplines.

SE is iterative—it derives and defines requirements at each level of the system, beginning at the top (the NAS level) and propagating those requirements through a series of steps that eventually leads to a physical design at all levels (i.e., from the system to its parts). Iteration and design refinement lead successively to preliminary design, detail design, and final approved design. At each successive level, there are supporting lower-level design iterations that are necessary to gain confidence for decisions. During these iterations, many concept alternatives are postulated, analyzed, and evaluated in trade studies. These iterative activities result in a multi-tier set of requirements. These requirements form the basis for structured verification of performance. SE closely monitors all development activities and integrates the results to provide the best solution at all system levels.

2.2 What Is a System?

A system is an integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. These integrated parts include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets. People from different disciplines and product areas have different perspectives on what makes up a system. For example, software engineers often refer to an integrated set of computer modules as a system. Electrical engineers might refer to a system as complex integrated circuits or an integrated set of electrical units. The FAA has an overarching system of systems called the NAS that includes, but is not limited to, all the airports, aircraft, people, procedures, airspace, CNS/ATM systems, and facilities.

At times, it is difficult to agree on what comprises a system, as it depends entirely on the focus of those who define the objective or function of the system. For example, if the objective is to print input data, a printer may be defined as the system. However, another might consider the electricity required for the printer. Expanding the objective to processing input data and displaying the results yields a computer as the system. Further expansion of the objective to include a capability for computing nationwide or worldwide and merging data/results to a database results in a computing network as the system, with the computer and printer(s) as subsystems of the system.

SE first defines the system at the top level, ensuring focus and optimization at that level, thus precluding narrow focus and suboptimization. It then proceeds to increasingly detailed lower levels until the system is completely decomposed to its basic elements. This hierarchy is described in the following paragraph.

2.2.1 System Hierarchy

A system may include hardware, software, firmware, people, information, techniques, facilities, services, and other support items. Figure 2.2-1 establishes a common reference for discussing the hierarchy of a system/subsystem within the NAS. Each system item may have its associated hierarchy. For example, the various software programs/components that may reside in a system has a commonly accepted hierarchy as depicted in Figure 2.2-2. The depths of this common hierarchy may be adjusted to fit the complexity of the system. Simple systems may have fewer levels in the hierarchy than complex systems and vice versa. Because there may be varying hierarchal models referenced in the realm of SE, it is important for those who define the objective or function of a given system/subsystem to also lay out the hierarchal levels of the system in order to define the system's scope.

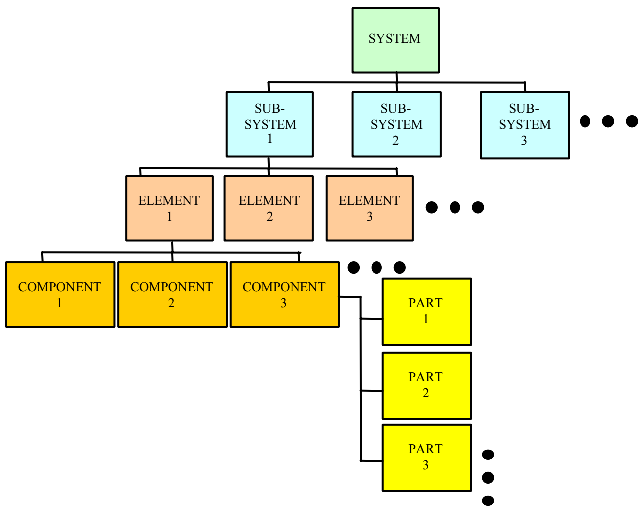


Figure 2.2-1. System Hierarchy

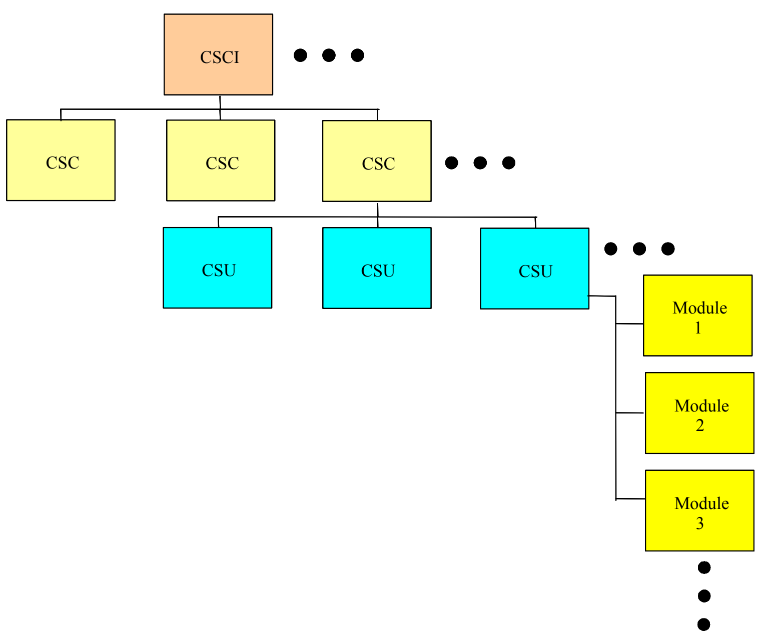


Figure 2.2-2. Common Software Hierarchy

Succeeding levels with the system/subsystem hierarchy are defined below:

- **System.** An integrated set of constituent parts that are combined in an operational or support environment to accomplish a defined objective. These parts include people, hardware, software, firmware, information, procedures, facilities, services, and other support facets.
- **Subsystem.** A system in and of itself (reference the system definition) contained within a higher-level system. The functionality of a subsystem contributes to the overall functionality of the higher-level system. The scope of a subsystem's functionality is less than the scope of functionality contained in the higher-level system.
- **Element.** An integrated set of components that comprise a defined part of a subsystem (e.g., the fuel injection element of the propulsion subsystem).
- **Component.** Composed of multiple parts; a clearly identified part of the product being designed or produced.
- **Part.** The lowest level of separately identifiable items within a system.
- **Software.** A combination of associated computer instructions and computer data definitions required to enable the computer hardware to perform computational or control functions.
- **Computer Software Configuration Item (CSCI).** An aggregation of software that is designed for configuration management and treated as a single entity in the Configuration Management process (Section 4.11).
- **Computer Software Component (CSC).** A functionally or logically distinct part of a CSCI, typically an aggregate of two or more software units.
- **Computer Software Unit (CSU).** An element specified in the design of a CSC that is separately testable or able to be compiled.
- **Module.** A program unit that is discrete and identifiable with respect to compiling, combining with other units, and loading.

2.3 Why Use System Engineering?

The need for effective SE is most apparent with large, complex system developments, such as weapons and transportation systems. However, SE is also important in developing, producing, deploying, and supporting much smaller systems, such as cameras and printers. The growing complexity in development areas has increased the need for effective SE. For example, about 35 years ago in the semiconductor industry, a single chip was no more complex than a series of a few gates or, at most, a four-stage register. Today, Intel's Pentium processor is far more complex, which immensely expands the application horizon but demands far more sophisticated analysis and discipline in design.

The movement to concurrent engineering as the technique for performing engineering development is actually performing good SE. SE provides the technical planning and control mechanisms to ensure that the activities/results of concurrent engineering meet overall system requirements.

A driving principle for SE is the teaming that often occurs during development programs. In this case, teaming is among several entities that may have different tools, analysis capabilities, and so on. SE principles defined in this manual may provide an improved ability to plan and control activities that require interaction/interface across boundaries.

The strongest argument for using the SE processes is that they increase the likelihood that needs are fully and consistently met in the final product. SE delivers first-time quality and a satisfied stakeholder.

3 SYSTEM ENGINEERING IN THE ACQUISITION MANAGEMENT SYSTEM PROGRAM LIFECYCLE

3.1 Functional View of the System Engineering Process

To better focus on the SE processes as they relate to each phase of the AMS, Figure 3.1-1 provides a high-level view of the various SE processes and how they functionally interact. These functional interfaces only represent the predominant interaction between each process. The interaction between processes at a lower level is much more involved (i.e., Figure 3.1-1 is a simplified view and does not depict all the ways that processes interface). Figure 3.1-2 is a functional N^2 diagram of SE that shows the actual work products exchanged between the various SE processes shown in Figure 3.1-1.

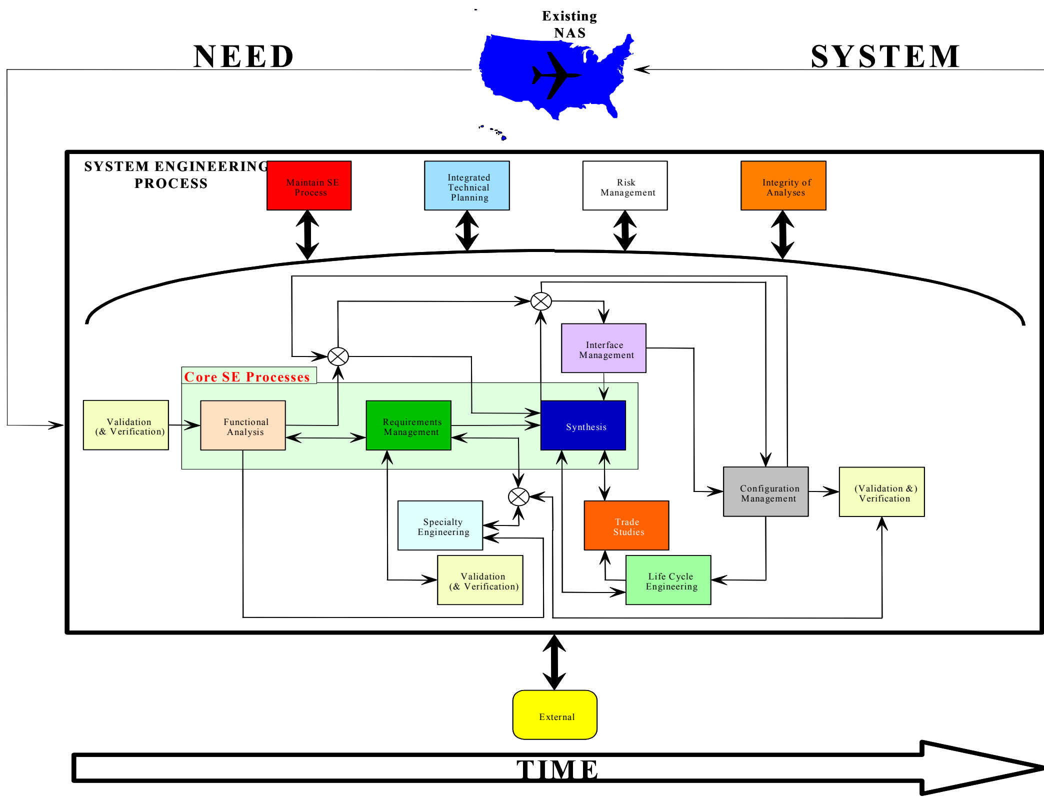


Figure 3.1-1. Functional Flow Diagram of System Engineering

In Figure 3.1-2, each SE process is laid out from left to right to notionally depict when in time each process is employed relative to another. The time arrow is *not* relative to the AMS lifecycle phases. It is recommended to note that overall SE, and many of the interactions at the lower levels, may be iterative in nature; thus, the left to right timeline is notional.

Figure 3.1-1 indicates that SE is initiated when there is a need; that is, a recognized shortfall in capability within the NAS. For example, the stakeholder need may arise as a result of a new service to be provided or with the advent of technological innovations to be leveraged to reap improvements in capacity, security, and/or safety. Once the need is validated, the Functional Analysis process (Section 4.4) is performed to develop a Concept of Operations (CONOPS). The Requirements Management process (Section 4.3) uses the CONOPS to develop an MNS, which is then fed back to Functional Analysis as input to develop the highest level of functional architecture for the new or modified system. The Requirements Management process uses this high-level functional architecture, as well as inputs from Specialty Engineering analyses, to develop requirements. These requirements are validated via the Validation and Verification process (Section 4.12). The interaction between Functional Analysis and Requirements Management is iterative, as the functional architecture and resulting requirements are decomposed to a level necessary to the appropriate requirements that describe the needed system characteristics. Synthesis (Section 4.5) then develops the physical architecture or design solution to those requirements.

Along with these initial SE activities, three overarching processes that interact with all SE processes are employed. These overarching processes continue throughout the system's lifecycle and are as follows:

- Integrated Technical Planning (Section 4.2)
  - Provides the technical guidance tools required to track and manage program activity
- Risk Management (Section 4.10)
  - Provides an organized, systematic decisionmaking approach to identify risks that affect achievement of program goals
  - Analyzes identified risks
  - Mitigates risks effectively
  - Tracks the progress of the mitigation efforts
- Integrity of Analyses (Section 4.9)
  - Ensures the provision of credible, useful, and sufficient data/results for program management's decisionmaking process
  - Ensures the integrity and fidelity of the various analysis tools

Once a valid set of requirements is obtained, the Synthesis process (Section 4.5) is initiated to define system elements and to refine and integrate these elements into a physical architecture. In addition to the requirements input into the Synthesis process, the functional architecture is provided to clarify and bound the system. The Trade Studies process (Section 4.6) and the Lifecycle Engineering process (Section 4.13) supply cost estimates to support the Synthesis process, which ultimately determines the design alternative that best satisfies the identified stakeholder need.

Interface Management (Section 4.7) plays a key role in ensuring that the various internal system pieces are coordinated as well as integrated with external systems. As the total system is decomposed via iterative interaction of Functional Analysis, Requirements Management, and Synthesis, physical and functional interfaces are identified and managed.

The results of these SE activities are continually brought under Configuration Management (Section 4.11). The system is developed according to the baseline design and verified with the Validation and Verification process (Section 4.12). With the system verified as able to meet the identified stakeholder need, it is deployed into the NAS. Although the discussion of this simplified view and description of SE was sequential, SE is truly iterative and employed continuously throughout the lifecycle of the system.

EXTERNAL	FAA Policy Integrated Program Schedule Corporate Strategy and Goals	Constraints FAA Management Decisions Govt & Intl Regulations & Statutes Legacy System Stakeholder Needs Standards Technology	FAA Management Decisions Legacy System	Constraints Legacy System Market Research Standards Technology	Market Research Technology Constraints Integrated Program Schedule	FAA Policy Legacy System Standards Interface Change Request	FAA Policy Standards	Technology Constraints	External Environmental Forces Constraints Technology Concerns/Issues Integrated Program Schedule	FAA Policy	Need Standards	Technology Test & Assessment Articles	Constraints External Environmental Forces Govt & Intl Regulations & Statutes Market Research FAA Policy Technology Concerns/Issues Integrated Program Schedule	
Integrated Program Plan	**INTEGRATED TECHNICAL PLANNING**	Integrated Lifecyle Plan Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan SEMP	Integrated Program Plan SEMP	Constraints Integrated Logisitics Support Plan Integrated Program Plan SEMP	Integrated Program Plan NAS Architecture SEMP	Integrated Lifecyle Plan Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan SEMP	Concerns/Issues Integrated Program Plan SEMP	Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan NAS Architecture SEMP	Integrated Program Plan Master Verification Plan NAS Architecture SEMP	Integrated Lifecyle Plan Integrated Program Plan NAS Architecture SEMP	
Requirements RVCD	Planning Criteria	**REQUIREMENTS MANAGEMENT**	Mission Need Statement Requirements	Requirements RVCD	Constraints Requirements	Requirements Mission Need Statement	Requirements RVCD	Requirements Tools/Analysis Requirements	Requirements RVCD Concerns/Issues	Requirements	Requirements	Requirements VRTM	Mission Need Statement Requirements	
	Concept of Operations NAS CONOPS Planning Criteria	Concept of Operations Functional Architecture OSED	**FUNCTIONAL ANALYSIS**	Functional Architecture OSED	Constraints Functional Architecture OSED	Concept of Operations Functional Architecture OSED	Concept of Operations Functional Architecture OSED	Tools/Analysis Requirements	Concerns/Issues	Functional Architecture OSED	Concept of Operations Functional Architecture OSED	Functional Architecture	OSED	
	Planning Criteria	Physical Architecture	Physical Architecture	**SYNTHESIS**	Physical Architecture Design Constraint Constraints Description of Alternatives	Operational Concept Demo Physical Architecture	Description of Alternatives Physical Architecture	Tools/Analysis Requirements	Concerns/Issues	Configuration Description	Operational Concept Demo Physical Architecture	Physical Architecture	Design Constraint Operational Concept Demo	
Trade Study Reports	Planning Criteria	Trade Study Reports		Trade Study Reports	**TRADE STUDIES**	Trade Study Reports		Tools/Analysis Requirements	Concerns/Issues				Trade Study Reports	
	Planning Criteria	Interface Control Documents Interface Requirements Documents	Interface Control Documents	Interface Requirements Documents	Constraints	**INTERFACE MANAGEMENT**	Interface Control Documents		Concerns/Issues	Interface Revision Proposal Interface Requirements Documents Interface Control Documents	Interface Requirements Documents	Interface Control Documents		
Certification Package	Planning Criteria	Design Analysis Reports Requirements	Design Analysis Reports	Design Analysis Reports	Design Analysis Report Constraints	Design Analysis Reports	**SPECIALTY ENGINEERING**	Design Analysis Reports Tools/Analysis Requirements	Concerns/Issues Design Analysis Reports		Demonstrations Design Analysis Reports	Demonstrations Verification Criteria Design Analysis Reports	Design Analysis Reports	
Credible Analysis Results	Analysis Criteria Planning Criteria	Analysis Criteria	Analysis Criteria	Analysis Criteria	Analysis Criteria Constraints		Analysis Criteria	**INTEGRITY OF ANALYSES**	Concerns/Issues Analysis Criteria	Credible Analysis Results		~~Analysis Criteria~~	Analysis Criteria	
Program Risk Register Program Risk Summary Risk Mitigation Plan Summary Risk Mitigation Plans	Planning Criteria	Risk Mitigation Plans		Risk Mitigation Plans	Constraints			Tools/Analysis Requirements	**RISK MANAGEMENT**					
	Planning Criteria	Approved Baseline Changes Configuration Status Report Updated Baselines		Configuration Status Report Updated Baselines Approved Baseline Changes	Constraints		Baselines	Baselines	Baselines Concerns/Issues	**CONFIGURATION MANAGEMENT**		Validation Reports Updated Baselines Configuration Status Report Approved Baseline Changes	Updated Baselines Configuration Status Report Approved Baseline Changes	
	Planning Criteria	Validation Reports	Validated Need		Constraints		Validation Reports		Concerns/Issues		**VALIDATION**			
	Planning Criteria	RVCD VRTM			Constraints			Tools/Analysis Requirements	Concerns/Issues			**VERIFICATION**		
	Planning Criteria			Lifecycle Cost Estimate	Lifecycle Cost Estimate Constraints			Tools/Analysis Requirements	Concerns/Issues Constraints				**LIFE CYCLE ENGINEERING**	
NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	NAS SEMP	**Maintain SE Process**

Figure 3.1-2. System Engineering Functional N^2 Diagram

3.2 Relationship of the System Engineering Processes to the Acquisition Management System Program Lifecycle

The program lifecycle includes all activities and products associated with a system, from initial inception to disposal and elimination, which falls in line with the global aspects of SE's definition. Definitions of the program lifecycle phases serve different purposes for different system processes. System sponsors shall use these phases and their associated milestones (e.g., Mission Need Decision (MND), Initial and Final Investment Decision, and In-Service Decision) to determine whether to continue or terminate the endeavor. Thus, the phases shall be used to measure a program's progress and develop input to the Joint Resources Council (JRC), which ultimately makes the noted decisions. Each program decision milestone is associated with a review, which are as follows:

- **JRC-1/MND milestone.** A briefing for review by the JRC is conducted before the MND.
- JRC-2a/Initial Investment Decision milestone. A briefing for review by the JRC is conducted before the Initial Investment Decision.
- **JRC-2b/Final Investment Decision milestone.** An Initial System Requirements review (ISRR) and a briefing for review by the JRC are conducted before the Final Investment Decision.
- **JRC-3/In-Service Decision milestone.** The in-service review (ISR) checklist is reviewed and briefed to the appointed decision authority before the In-Service Decision.

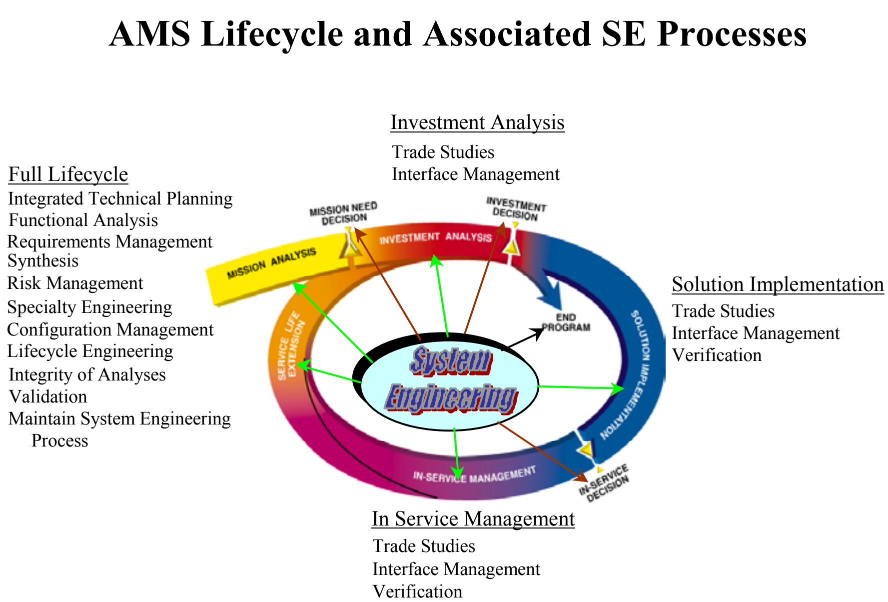


Figure 3.2-1. Focus of System Engineering Effort in the Acquisition Management System Lifecycle Phases

As shown in Figure 3.2-1, SE lays out and supports the technical and programmatic activities as the program moves through these phases. The SE processes support the lifecycle phases defined by the AMS and provide management visibility into the operation of the program, facilitating risk reduction through early identification of issues and, thus, allowing better management. Therefore, cost is reduced through earlier recognition and correction of problems (Figure 1.3-1). Support organizations are able to gauge and plan their work to support each phase.

Any or all of the SE processes may be applied throughout the entire lifecycle, regardless of the phase. However, Figure 3.2-1 shows that the predominance of a specific SE process depends on the phase of the lifecycle. For example, there are certain elements of SE employed during the Mission Analysis (MA) phase more so than during the SI phase. The Validation process (Section 4.12) is used more heavily during MA when compared to Verification (Section 4.12). Likewise, the Verification process is used more heavily during SI when compared to Validation.

Because SE establishes system requirements and overall system architecture, it is a dominating process during the MA and IA phases. During this time, mission needs, CONOPS, and requirements are analyzed and documented to support both functional and physical system decomposition to greater detail. Program plans are developed to guide and control subsequent activity consistent with the overall system requirements. Alternatives are developed and synthesized to identify the most viable approach. Trade Studies (Section 4.6) are conducted to provide input to the Synthesis process (Section 4.5) to facilitate selection of the most viable approach. The Trade Studies data supports the selection and approval to proceed with an Acquisition Program Baseline (APB).

During the SI phase, proposed system design alternatives are reviewed against requirements and selection criteria. When a system design is selected, iterations of SE are performed to completely decompose the system to a set of products (e.g., hardware, software, people) that may be built/programmed (or trained or otherwise provided) and verified. SE elements are used to maintain overall integration (cost, schedule, and technical) of the lower-level product development activities based on overall system requirements.

After the system design has been tested and accepted, SE activities shift to deployment and transition of the production systems to the field. As systems enter the In-Service Management lifecycle phase, SE is reiterated to ensure effective incorporation of system design changes due to problem fixes, new functionality, or product obsolescence. These activities continue through the remainder of the system's service life until disposal.

In addition to the functional view of SE (Figure 3.1-1), the SE model may be depicted as a cube (Figure 3.2-2) in order to emphasize the iterative nature of SE throughout the AMS lifecycle. The vertical dimension depicts the system hierarchy, which emerges from the iterative use of SE. The horizontal dimension indicates the SE elements, and the third dimension contains the phases of development. This representation shows that SE applies across all phases and to all levels of the system hierarchy.

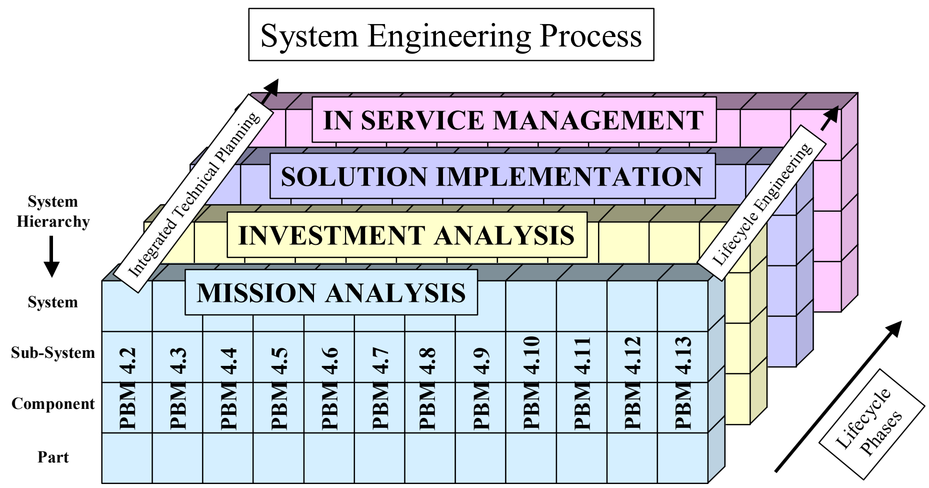


Figure 3.2-2. The System Engineering Process Cube

Each major program phase has a progressively more mature, detailed, and changing focus. SE responds with a different emphasis as the program progresses through its development and deployment. The application of SE, as defined in this manual, shall be continually tailored to the specific needs of each program and its current phase.

3.3 Program Lifecycle

This section addresses each phase of the AMS lifecycle and correlates the phases to SE activities. Data flow diagrams (DFD) highlight the SE processes and work products that are predominant during that time.

In addition, a table is included with each phase discussion that:

- Identifies the SE work products that are inputs and/or outputs to the addressed phase
- Identifies work products generated from processes external to SE that are necessary to initiate SE activities within the given phase

The following legend in Table 3.3-1 applies to each of these tables.

Table 3.3-1. Legend for System Engineering Work Products Inputs/Outputs Tables

Abbreviation		Meaning
C	=	Conceptual draft (precedes initial draft); the general notion and structure of the document has been created with minimal content
CM	=	Configuration Management
EXT	=	External to SE
F	=	Final draft; document is complete, accurate, and awaiting signature
FA	=	Functional Analysis
I	=	Initial draft; the document has been populated with the majority of required content, but it still requires review for accuracy of information
IA	=	Integrity of Analyses
IM	=	Interface Management
ISRR	=	Initial System Requirements Review
LC	=	Lifecycle Engineering
MSE	=	Maintain System Engineering
RM	=	Requirements Management
RSK	=	Risk Management
S	=	Synthesis
SD	=	Sustaining Document For work products that are formal documents, the documents are sustained in the given phase For work products that are not formal documents, the products are introduced, further developed, or sustained in the given phase
SpecEng	=	Specialty Engineering
ITP	=	Integrated Technical Planning
TS	=	Trade Studies
Val	=	Validation

Table 3.3-2 gives a high-level view of the various SE work products and the timeframe during which they are developed.

Table 3.3-2. System Engineering Work Product/ Acquisition Management System Milestone Matrix

	PROGRAM MILESTONES				
WORK PRODUCT	**JRC1**	**JRC2A**	**ISRR**	**JRC2B**	**JRC3**
Acquisition Program Baseline[1]		C	I	F	
Analysis Criteria	I	F	SD	SD	SD
Approved Baseline Changes					SD
Baselines				SD	SD
Certification Package				I	F
Concept of Operations	I	F			
Concerns/Issues	SD	SD	SD	SD	SD
Configuration Description				I	F
Configuration Status Report					SD
Constraints	SD	SD	SD	SD	SD
Corporate Strategy and Goals	SD	SD	SD	SD	SD
Credible Analysis Results	SD	SD	SD	SD	SD
Demonstrations		SD	SD	SD	SD
Description of Alternatives	I	F			
Design Analysis Reports	SD	SD	SD	SD	SD
Design Constraint	SD	SD	SD	SD	SD
External Environmental Forces	SD	SD	SD	SD	SD
FAA Management Decisions	SD	SD	SD	SD	SD
FAA Policy	SD	SD	SD	SD	SD
Functional Architecture	C	I	F[1]	SD	SD
Government and International Regulations and Statutes	SD	SD	SD	SD	SD
Integrated Lifecycle Plan	C	I	F	SD	SD
Integrated Program Plan	C	I	F	SD	SD
Integrated Program Schedule	C	I	F	SD	SD
Interface Change Request					SD
Interface Control Documents			C	I	F
Interface Requirements Documents		I	F	SD	SD
Interface Revision Proposal					SD
Legacy System	SD	SD	SD	SD	SD
Lifecycle Cost Estimate	C	I		F	
Market Research	SD	SD	SD		
Master Verification Plan		I	F	SD	SD
Mission Need Statement	F				
NAS Architecture	SD	SD	SD	SD	SD
NAS Concept of Operations	SD	SD	SD	SD	SD
NAS System Engineering Management Plan	SD	SD	SD	SD	SD
Need	SD				
Operational Concept		SD	SD		

	PROGRAM MILESTONES				
WORK PRODUCT	**JRC1**	**JRC2A**	**ISRR**	**JRC2B**	**JRC3**
Demonstrations					
Operational Services and Environmental Description	C	I	F		
Physical Architecture		C		I	F
Planning Criteria	SD	SD	SD	SD	SD
Program Risk Register			SD	SD	SD
Program Risk Summary		SD	SD	SD	SD
Requirements	I		F[2]	SD	SD
Requirements Verification Compliance Document					F
Risk Mitigation Plan Summary		SD	SD	SD	SD
Risk Mitigation Plans		SD	SD	SD	SD
Stakeholder Needs	I	F	SD	SD	SD
Standards			SD	SD	SD
Statement of Work[1]			I	F	
System Engineering Management Plan		I	F		
Technology	SD	SD	SD	SD	SD
Test and Assessment Articles					F
Tools/Analysis Requirements		SD	SD	SD	SD
Trade Study Reports		SD	SD	SD	SD
Updated Baselines					SD
Validated Need	F				
Validation Reports	SD	SD	SD	SD	SD
Verification Criteria		SD	SD	SD	SD
Verification Requirements Traceability Matrix	C	I	F	SD	SD
Work Breakdown Structure[1]	C	I	F		

1. This work product is not produced via the SE process. It is listed here as a point of reference since SE provides substantial input into the development of this work product.
2. This does not imply that there is no further decomposition (e.g., "Final" requirements at this point in time is with respect to the final Requirements Document (fRD), yet further decomposition takes place to generate a specification).

3.3.1 Mission Analysis Phase

3.3.1.1 Mission Analysis Phase Objectives

The basic objective of the MA phase is to correctly identify and quantify a need so that the FAA may begin a program to resolve that need. The primary outputs of this phase are the MNS or the modification of an existing MNS and design constraints. The MA phase ends with an MND. In most cases, the MA consists of activities to validate high-level needs and to seek approval to proceed to the next phase. It has two dimensions: a technical dimension and a program-planning dimension. The technical dimension is to ensure that a complete understanding of the demand for services has been identified and quantified, which is accompanied by identification and quantification of existing and projected supply of services. NAS shortfalls and potential technological opportunities shall be identified and quantified. The program-planning dimension is to identify potential project-scope and estimated resource requirements.

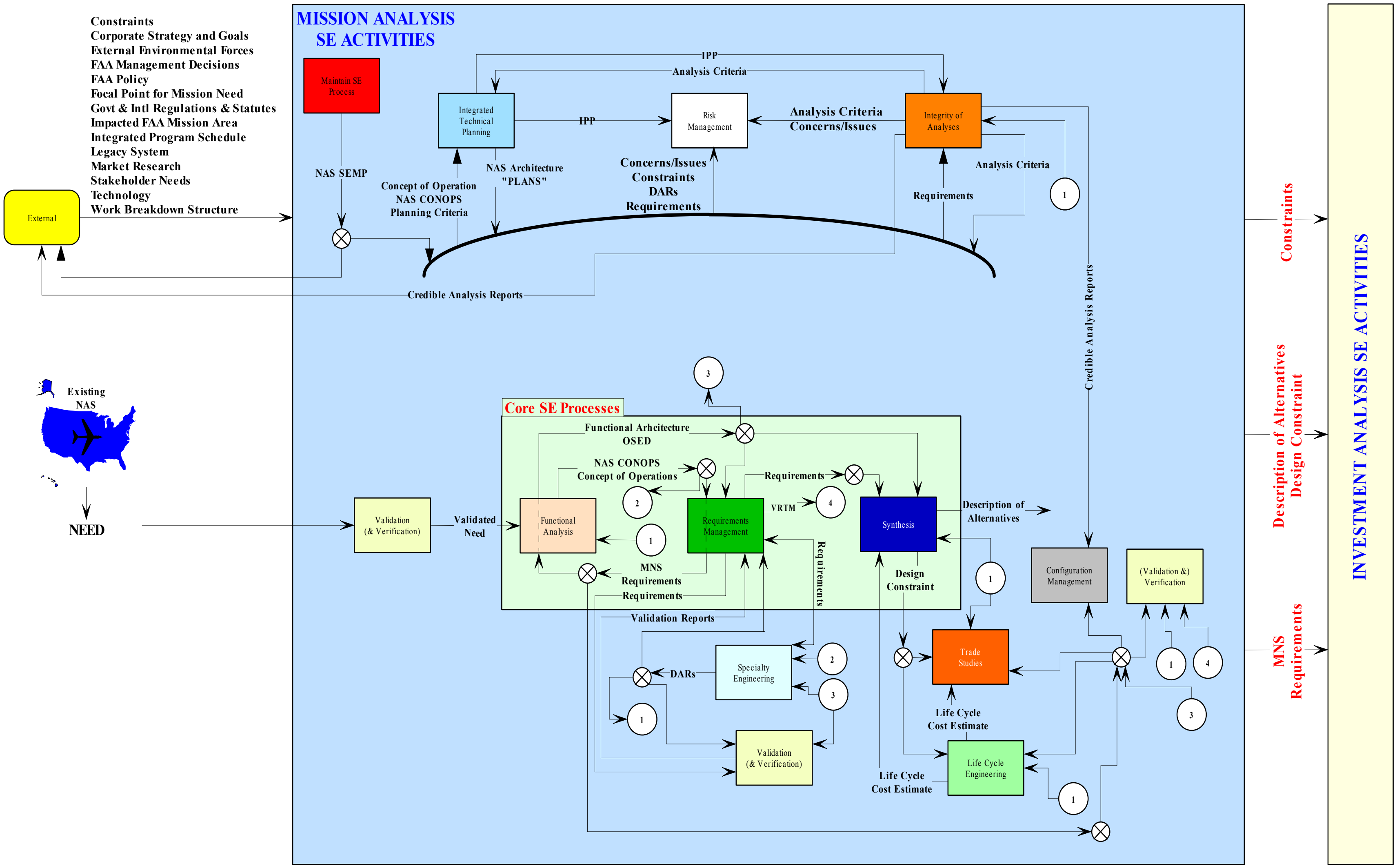
3.3.1.2 System Engineering Activities

Figure 3.3-1 is an overview of the primary SE activities that occur during MA. SE is initiated when a stakeholder need is recognized. If the stakeholder need is valid, SE continues to better understand functionally what is required to best meet the stakeholder need. A CONOPS is developed via Functional Analysis (Section 4.4) and is used in Requirements Management (Section 4.3) to develop the MNS. The MNS is a primary SE output during the MA phase; it also drives the continued iterations of Functional Analysis and Requirements Management. The interaction of these two processes results in a high-level functional decomposition and, likewise, a high-level requirements decomposition. The resulting set of requirements is validated and is used, along with the high-level functional architecture, during the Synthesis process (Section 4.5) to develop a description of alternatives and associated design constraints. At this point in time, these alternatives and constraints are very high-level and are used as primary input into the IA phase to provide scope for the program.

In addition to the core Functional Analysis, Requirements Management, and Synthesis activities, other SE processes are initiated during the MA phase. These activities involve the technical planning necessary to provide proper guidance for SE activities throughout the system's lifecycle; identification of risks and plans to mitigate those risks; and establishment of analysis criteria for the various analyses that occur when designing the system. Any of the SE activities may surface concerns/issues to be processed by Risk Management (Section 4.10), as well as constraints to bound the activities of the Trade Studies process (Section 4.6) that occur during the follow-on phases.

Electronic Industries Association (EIA) 731-2 defines a constraint as (1) a restriction, limit, or regulation or (2) A type of requirement that is not tradeable against other requirements. Constraints describe what is not included in the program. These items define work that might be expected but will not be done. Often, these are defined in work scope statements given by project contributors during the cost definition process. This includes gathering stakeholder inputs on "needs" and "wants," system constraints (costs, technology limitations, and applicable specifications/legal requirements), and system "drivers" (such as competition capabilities, military threats, and critical environments). Tradeoffs should be done on the desirability of including a performance capability in the system versus a more affordable (or less risky) system approach. This tradeoff process often begins well before a firm set of needs is established and continues throughout the MA phase in which stakeholder interaction on specific items proposed may take place. Constraints may be further adjusted throughout later AMS phases. Like behavior deficiencies or shortfalls, these are excellent opportunities for preplanned product improvement. Funding, personnel, facilities, manufacturing capability, critical resources, or other reasons cause the existence of constraints. The reason for each constraint should be understood.

Risk always is present in the lifecycle of both commercial and military systems. The system may be intended for technical accomplishments near the limits of the state of the art, creating technical risk. System development may be rushed to deploy the system as soon as possible to meet an imminent threat, leading to schedule risk. All systems are funding-limited so that cost risk is present. Risk can be introduced by external constraints or can develop from within the program, since technical risk can create schedule risk that in turn can create cost risk.



529

530 Figure 3.3-1. Mission Analysis System Engineering Activities

Table 3.3-3 summarizes the MA SE inputs and outputs.

Table 3.3-3. Mission Analysis System Engineering Inputs and Outputs

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Analysis Criteria	IA		I
Concept of Operations	FA		I
Concerns/Issues	ALL		SD
Constraints	ALL except TS		SD
Corporate Strategy and Goals	EXT	SD	
Credible Analysis Results	IA		SD
Description of Alternatives	S		I
Design Analysis Reports	SpecEng		SD
Design Constraint	S		SD
External Environmental Forces	EXT	SD	
FAA Management Decisions	EXT	SD	
FAA Policy	EXT	SD	
Functional Architecture	FA		C
Government and International Regulations and Statutes	EXT	SD	
Integrated Lifecycle Plan	ITP		C
Integrated Program Plan	ITP		C
Integrated Program Schedule	EXT	C	
Legacy System	EXT	SD	
Lifecycle Cost Estimate	LC		C
Market Research	EXT	SD	
Mission Need Statement	RM		F
NAS Architecture	ITP	SD	
NAS Concept of Operations	FA	SD	
NAS System Engineering Management Plan	MSE	SD	
Need	EXT	SD	
Operational Services and Environmental Description	FA		C
Planning Criteria	ALL except ITP		SD
Requirements*	RM		I
Stakeholder Needs	EXT	SD	
Technology	EXT	SD	
Validated Need	Val		F
Validation Reports	Val		SD
Verification Requirements Traceability Matrix	RM		C
Work Breakdown Structure	EXT	C	

* Requirements expressed in the Initial Requirements Document (iRD).

NOTE: See Table 3.3-1 for legend.

3.3.1.3 Mission Analysis Entrance Criteria

There are no other entrance criteria beyond the concept of a given "need" and approval to initiate SE efforts during the MA phase.

3.3.1.4 Mission Analysis Exit Criteria

The following criteria shall be satisfied (to the satisfaction of program management and its review authority) before the program enters the IA phase:

- Completion of all work products identified as MA outputs to the version level specified
- Approval of the MND, thereby authorizing the program to proceed to the IA phase

3.3.1.5 System Engineering Element Tasks in Mission Analysis

In addition to the tasks identified below, each SE Element active during this phase shall surface concerns/issues that present risk to the program, as well as any constraints that bound future Trade Studies (Section 4.6).

3.3.1.5.1 Tasks for the Integrated Technical Planning Element

Although the major planning activities occur in the following IA phase(i.e., after the JRC1/MND) the following plans shall be completed by the end of MA to guide initial IA activities:

- Conceptual draft of the Integrated Program Plan (IPP) (with details for the mission needs analysis and IA items) to include the following planning information:
  - Configuration Management (Section 4.11) to control program documentation, including requirements that may change
  - Risk Management (Section 4.10) to lay out program policy for risk assessment and mitigation, including program preparation activities
  - Analysis Management (Section 4.9)
  - Requirements Management (Section 4.3)
- Conceptual draft of the Integrated Lifecycle Plan

3.3.1.5.2 Tasks for the Requirements Management Element

The primary tasks of the Requirements Management process (Section 4.3) are:

- Develop the MNS (new or modified)
- Develop the Initial Requirements Document (iRD; new or modified) to include intended service life, the initial list of stakeholders, and a conceptual draft of the Verification Requirements Traceability Matrix (VRTM)

At this time, a means for tracking and tracing requirements (e.g., via a database) shall be established.

3.3.1.5.3 Tasks for the Functional Analysis Element

Functional Analysis (Section 4.4) of the operational system begins in this phase by:

- Developing an initial draft of a CONOPS
- Developing a conceptual draft of the Operational Services and Environmental Description (OSED)
- Developing the conceptual version of the first-level functional architecture

Developing the functional architecture involves identifying at least the high-level functions to be performed to accomplish the required mission operations. Thus, high-level functional flow diagrams (FFD) are created. The decision to analyze the functions to lower levels depends on the presence of the right expertise and available information to conduct these analyses. Insofar as a conceptual product is defined, the primary rationale at this point is to provide a concise, clear description of the system for the MND without precluding any creativity in developing concepts to support the high-level functions.

3.3.1.5.4 Tasks for the Synthesis Element

The role of Synthesis (Section 4.5) is to create sufficient alternative high-level concepts that might satisfy the service needs and perform the high-level functions to define the program space (i.e., to show the range of possibilities to explore). Focusing too soon on a feasible concept as *the* final solution—a typical difficulty—stifles creativity and reduces potential benefits and shall be avoided at all costs. Several wide-ranging, yet viable, concepts are valuable to inspire creativity in concept development. Synthesis activities during this phase include:

- Producing initial drafts of description of alternatives for at least two concepts in order to give the IA team a sufficient understanding of the program scope
- Identifying design constraints

3.3.1.5.5 Tasks for the Specialty Engineering Element

During the MA phase, Specialty Engineering (Section 4.8) develops high-level design analysis reports (DAR) to support requirements development, Validation (Section 4.12) of existing requirements, Risk Management (Section 4.10), and Synthesis (Section 4.5) (if required).

3.3.1.5.6 Tasks for the Integrity of Analyses Element

During the MA phase, the Integrity of Analyses process (Section 4.9) produces the analysis criteria for all immediately foreseen required analyses. Credible analysis results are generated for analyses initiated and completed during the MA phase.

3.3.1.5.7 Tasks for the Validation Element

Validation (Section 4.12) is performed on the stakeholder need and initial high-level requirements.

3.3.1.5.8 Tasks for the Lifecycle Engineering Element

Lifecycle Engineering (Section 4.13) develops a preliminary lifecycle cost estimate and a conceptual draft of the Integrated Lifecycle Plan.

3.3.2 Investment Analysis Phase

The IA phase of the AMS lifecycle has the following objectives:

- Further translate the mission needs into requirements and eventually into specifications
- Complete the CONOPS
- Complete the IPP and all additional program plans
- Complete the functional architecture to a level appropriate to requirements (i.e., those levels needed to support development of the final Requirements Document (fRD) or system specification)
- Develop potential solutions
- Analyze alternative solutions and determine the optimum solution from a NAS perspective
- List and analyze all programmatic risks
- Provide risk mitigation plans with associated costs
- Modify the architecture to the recommended solution
- Provide input for APB development

IA begins with the approval of a mission need and ends with an Investment Decision. There are two SE stages during the IA phase: the initial IA stage (or the JRC 2A stage) and the final IA stage (or the JRC 2B stage).

Figure 3.3-2 depicts these two stages as they relate to AMS milestones.

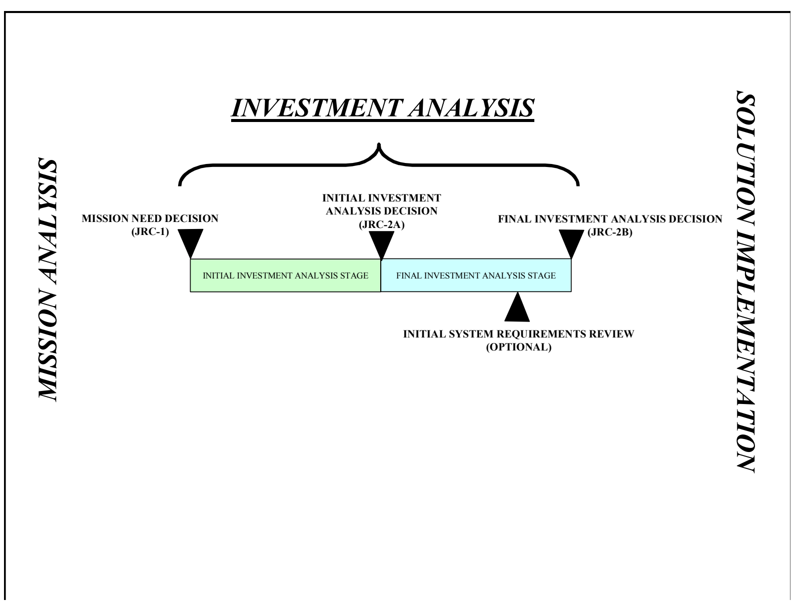


Figure 3.3-2. Investment Analysis System Engineering Stages

3.3.2.1 System Engineering Activities

The SE activities occurring during the IA phase appear in Figure 3.3-3. The core SE processes continue, in an iterative fashion, to produce a design that meets the stakeholder need. Functional Analysis (Section 4.4) continues to decompose the functions to lower levels. These lower-level functions are used to develop more detailed requirements that, in turn, are used to bound the next level of functional decomposition. Specialty Engineering (Section 4.8) feeds this process by providing various DARs to further refine the requirements and manage various risk facets. Requirements generated from this interaction are then validated; and once validated, they are fed into the Synthesis process (Section 4.5), where alternative solutions to meet these requirements are developed. The Trade Studies process (Section 4.6) and the Lifecycle Engineering process (Section 4.13) are both heavily employed during this phase to provide Synthesis with the data required to make an informed decision concerning the best solution set. The resulting physical architecture, in conjunction with the functional architecture, is used in Interface Management (Section 4.7) to develop IRDs and eventually Interface Control Documents (ICD).

The primary outputs from the SE efforts in this phase are the functional and physical architectures and associated requirements in the form of IRDs and the fRD. The APB and statement of work (SOW) are developed from external processes to SE but are heavily based on SE input.

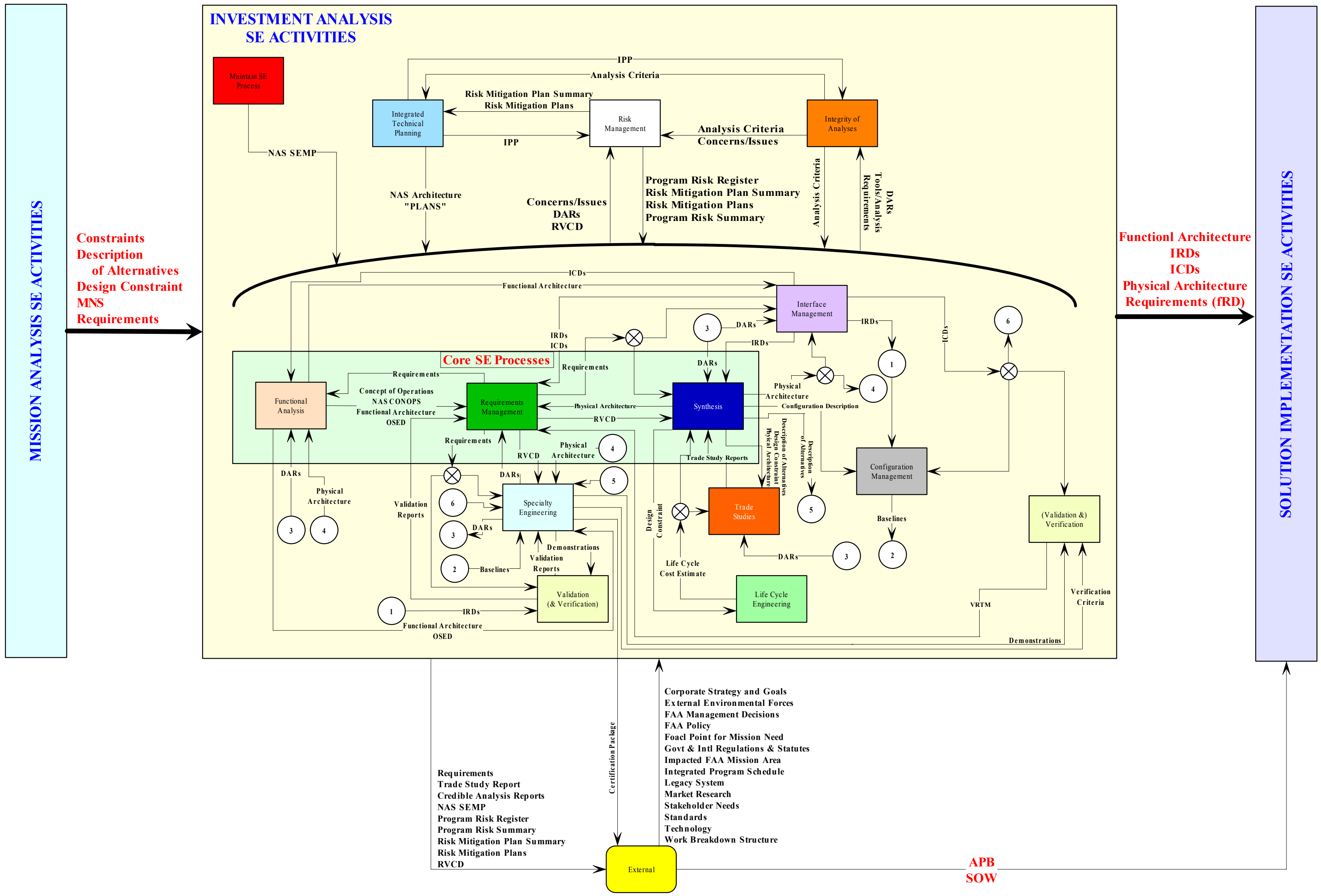


Figure 3.3-3. Investment Analysis System Engineering Activities

3.3.2.2 Initial Investment Analysis Stage

3.3.2.2.1 Initial Investment Analysis Stage Objectives

Initial IA is the first of two stages in the IA phase. The main objective of this stage is to develop a set of alternative solutions to the requirements and then select the alternative that provides the most balanced solution to the need. To accomplish this objective, SE analyzes the high-level requirements so the needs, objectives, requirements, and operating scenarios are fully understood and integrated. Because these top-level requirements typically lack the details required to execute an end-item design, it is important that stakeholders adequately communicate to eliminate gaps in understanding requirements. To this end, the needs, mission(s), and utilization environments are analyzed, interpreted, and coordinated with stakeholders to determine system requirements. This stage also identifies the required disciplines needed to support the effort as well as a review indicating that all stakeholders have been identified.

In this stage, the system functional architecture is expanded. The functions are then transformed into more detailed system requirements that are resolved in the system physical architectures. Higher-level requirements constrain the next lower functional architecture. Also, the interfaces between the functions, subsystems, and elements that comprise the total system are documented. Functional and performance requirements are allocated to those subsystems and elements. Detailed subsystem and element requirements and constraints are developed, and subsystem and element concepts are traded and selected.

Further development and evaluation of alternative concepts pave the way for selection of the best concept. Each candidate concept is validated to ensure feasibility and that all requirements have been satisfied. Candidate concepts that fail to meet requirements are modified or discarded. More detailed concept development and analyses are then conducted to characterize each of the concepts to add maturity and facilitate selection of the best alternative. Trade Studies (Section 4.6) are conducted to select from alternative approaches to satisfy requirements; identify preferred technologies and processes; define support concepts; assess lifecycle cost elements; and quantify program risks. Down-selection criteria are established based on design sensitivities, cost/benefit ratios, schedules, programmatic constraints and requirements, risks, corporate strategies, and other considerations, as applicable. A single approach shall be selected before the close of this stage, and the details of this baseline are then placed under NAS Configuration Management. The cost/benefit analysis that results in the selection of the best concept is documented and made a part of the program documentation.

Table 3.3-4 summarizes initial IA stage inputs and outputs.

Table 3.3-4. Initial Investment Analysis Stage System Engineering Inputs and Outputs

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Acquisition Program Baseline[1]	EXT		C
Analysis Criteria	IA	I	F
Concept of Operations	FA	I	F
Concerns/Issues	ALL	SD	SD
Constraints	ALL except TS	SD	SD

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Corporate Strategy and Goals	EXT	SD	
Credible Analysis Results	IA	SD	SD
Demonstrations	SpecEng		SD
Description of Alternatives	S	I	F
Design Analysis Reports	SpecEng	SD	SD
Design Constraint	S	SD	SD
External Environmental Forces	EXT	SD	
FAA Management Decisions	EXT	SD	
FAA Policy	EXT	SD	
Functional Architecture	FA	C	I
Government and International Regulations and Statutes	EXT	SD	
Integrated Lifecycle Plan	ITP	C	I
Integrated Program Plan	ITP	C	I
Integrated Program Schedule	EXT	I	
Interface Requirements Document	IM		I
Legacy System	EXT	SD	
Lifecycle Cost Estimate	LC	C	I
Market Research	EXT	SD	
Master Verification Plan	ITP		I
Mission Need Statement	RM	F	
NAS Architecture	ITP	SD	
NAS Concept of Operations	FA	SD	
NAS System Engineering Management Plan	MSE	SD	
Operational Concept Demonstrations	S		SD
Operational Services and Environmental Description	FA	C	I
Physical Architecture	S		C
Planning Criteria	ALL except ITP	SD	SD
Program Risk Summary	RSK		SD
Requirements[2]	RM	I	I
Risk Mitigation Plan Summary	RSK		SD
Risk Mitigation Plans	RSK		SD
Stakeholder Needs	EXT	I	
System Engineering Management Plan	ITP		I
Technology	EXT	SD	
Tools/Analysis Requirements	ALL except EXT, ITP, IM, IA, CM, Val		SD
Trade Study Report	TS		SD
Validation Reports	Val	SD	SD
Verification Criteria	SpecEng		SD
Verification Requirements Traceability Matrix	RM	C	I

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Work Breakdown Structure	EXT	C	
1. This work product is not an output of SE per se, but it is identified in order to provide context for the level of SE input to its development. 2. The iRD is updated during Initial Investment Analysis. NOTE: See Table 3.3-1 for legend.			

3.3.2.2.2 Initial Investment Analysis Stage Entrance Criteria

These criteria include the following:

- An MND approving continuation of the program to the IA phase
- MA output

3.3.2.2.3 Initial Investment Analysis Stage Exit Criteria

These criteria include the following:

- All work products identified as initial IA outputs have been completed to the version level specified
- Required disciplines have been identified
- Trade Studies (Section 4.6) have been planned
- Initial baseline planning has been completed
- The initial IA decision has been made, authorizing the program to proceed to the final IA stage

3.3.2.2.4 System Engineering Element Tasks

In addition to the tasks identified below, each SE Element active during this phase shall surface concerns/issues that present risk to the program, as well as any constraints that bound future Trade Studies (Section 4.6). Furthermore, those active SE Elements that involve analysis shall develop their requirements for analysis (e.g., necessary tools, required analyst levels of competencies).

3.3.2.2.4.1 Tasks for the Integrated Technical Planning Element

In this stage of technical plans development, the following conceptual drafts, developed during MA, are updated to initial drafts:

- IPP
- Integrated Lifecycle Plan

In addition, the SEMP and Master Verification Plan (MVP) are created and developed to an initial draft state by the end of this stage.

3.3.2.2.4.2 Tasks for the Requirements Management Element

The main task of Requirements Management (Section 4.3) is to update the Initial Requirements Document (iRD). Additional activities are focused on capturing the allocation of requirements to the conceptual version of the physical architecture, via a database, and updating the conceptual draft of the VRTM to initial draft.

3.3.2.2.4.3 Tasks for the Functional Analysis Element

The Functional Analysis process (Section 4.4) focuses on finalizing the CONOPS, updating the OSED to an initial draft, and further decomposing the next level of functions into sequenced and traceable functional architectures (dependent upon the availability and detail of requirements documentation).

3.3.2.2.4.4 Tasks for the Synthesis Element

During Synthesis (Section 4.5), conceptual versions of the physical architectures for the set of alternatives are produced and the description of alternatives are further refined. In conjunction with Functional Analysis (Section 4.4) and Trade Studies (Section 4.6), Synthesis (Section 4.5) is the heart of the IA process during this stage. It performs the design analysis of the benefits, strengths, and weaknesses of the alternative concepts against a common set of requirements and selection criteria to determine their relative merits. Down-selection to a preferred solution is the result of this design analysis. Design constraints are identified during this analysis and fed to Lifecycle Engineering (Section 4.13) and Trade Studies (Section 4.6) activities. Operational concept demonstrations are also conducted to support these activities.

3.3.2.2.4.5 Tasks for the Trade Studies Element

Trade Studies (Section 4.6) are conducted at all system levels to ensure performance effectiveness, application of technology and processes, minimum cost, and supportability and affordability, and to generally provide input for the selection of the best concept. Identification of the best concept is based on the criteria developed specifically for the system, its mission, operations concept, performance requirements, programmatic constraints, and other applicable factors. The trade study report documents the findings and is used as data to support and justify the down-selection to one concept.

3.3.2.2.4.6 Tasks for the Interface Management Element

This element begins to identify the external interfaces to the system. The conceptual and then initial draft(s) of the Interface Requirements Document(s) (IRD) are developed during this phase to capture these interfaces. Conceptual drafts of the ICDs are initiated. Functional and physical interfaces internal to the system are also identified and captured via interface control scope sheets.

3.3.2.2.4.7 Tasks for the Specialty Engineering Element

During Specialty Engineering (Section 4.8), tailored analyses are initiated to derive requirements, support trades, and identify risks. The System Safety discipline produces the comparative safety analysis. The system baseline design is established, and the scope, ground rules, and assumptions of analysis are defined. Security shall initiate a risk analysis and vulnerability analysis, document program security level, and commence personnel security actions. DARs are produced and verification criteria are established. In addition to these activities, demonstrations may be conducted.

3.3.2.2.4.8 Tasks for the Integrity of Analyses Element

The main task for Integrity of Analyses (Section 4.9) is to finalize the analysis criteria, which is accomplished by:

- Identifying analysis needs
- Verifying that the right tools are available
- Verifying that input data is correct
- Verifying that analysts are competent
- Verifying that analytical compatibility rules are documented

Credible analysis results are generated for the latest completed analyses.

3.3.2.2.4.9 Tasks for the Risk Management Element

The identification and analysis of risks begins during Risk Management (Section 4.10) as soon as the stakeholder need(s) is translated into functional requirements. Typical avenues of search include Specialty Engineering disciplines and capabilities (e.g., personnel, facilities, and tools) compared against the concepts, readiness of technology for the functions and concepts that evolve, and likelihood of cost restrictions. At this phase, identified risk areas shall be monitored, and only the nature of mitigation strategies shall be identified. As the program unfolds, the mitigation plans may be finalized. Thus, at this point, Risk Management activities involve:

- Creating a program risk summary
- Creating preliminary risk mitigation plans
- Developing a risk mitigation plan summary

3.3.2.2.4.10 Tasks for the Validation Element

During the Validation process (Section 4.12), validation reports are generated to document the initial results in requirements validation.

3.3.2.2.4.11 Tasks for the Lifecycle Engineering Element

An initial draft of the lifecycle cost estimates that are based on remaining concept alternatives are developed in Lifecycle Engineering (Section 4.13). The existing set of validated requirements, identified design constraints, DARs, and trade study reports are used to drive this estimate. The Integrated Lifecycle Plan is updated to reflect the maturing program planning and captures planning for real estate, deployment and transition, integrated logistics support, sustainment/technology evolution, and disposal.

3.3.2.3 Final Investment Analysis Stage

3.3.2.3.1 Final Investment Analysis Stage Objectives

The main objective of this stage, which consists of two parts with an Initial System Requirements Review (ISRR) milestone near the end of the stage, is to establish validated requirements and document the complete functional baseline for the selected solution. This stage further refines the architecture. Selected subsystem and element concepts are expanded with details to verify that they meet high-level requirements and constraints. Also, the interfaces between the elements that comprise the subsystems are documented. Functional and performance requirements and constraints are allocated to those elements, and packages defining development of the elements are created.

A business case is developed that illustrates all stakeholder costs and obligations, providing details of both agency and nonagency resource demands. Program requirements are completed, corrected, and documented in the fRD. Also, the interfaces between the components that comprise the elements are documented, and functional and performance requirements are allocated to those components. The planned procurement specifications are listed, and the APB is completed. A successful IA leads to the JRC-2B decision for the program.

An ISRR is held toward the end of this stage, usually 1 to 2 months prior to JRC-2B, primarily as a means to review and agree upon the final set of system requirements. The fRD is reviewed at this time in preparation for the JRC-2B. Appendix C contains an ISRR checklist to use in preparing this review milestone.

The discussion of SE activities and associated inputs and outputs for the final IA phase is presented below in two parts to account for the ISRR milestone.

3.3.2.3.2 Final Investment Analysis Pre-Initial System Requirements Review

Table 3.3-5 summarizes final IA pre-ISRR inputs and outputs.

Table 3.3-5. Final Investment Analysis Pre-Initial System Requirements Review Inputs and Outputs

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Acquisition Program Baseline[1]	EXT	C	I
Analysis Criteria	IA	F	SD
Concept of Operations	FA	F	
Concerns/Issues	ALL	SD	SD
Constraints	ALL except TS	SD	SD
Corporate Strategy and Goals	EXT	SD	
Credible Analysis Results	IA	SD	SD
Demonstrations	SpecEng	SD	SD
Description of Alternatives	S	F	
Design Analysis Reports	SpecEng	SD	SD
Design Constraint	S	SD	SD
External Environmental Forces	EXT	SD	

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
FAA Management Decisions	EXT	SD	
FAA Policy	EXT	SD	
Functional Architecture[2]	FA	I	F
Government and International Regulations and Statutes	EXT	SD	
Integrated Lifecycle Plan	ITP	I	F
Integrated Program Plan	TP	I	F
Integrated Program Schedule	EXT	F	
Interface Control Document	IM		C
Interface Requirements Document	IM	I	F
Legacy System	EXT	SD	
Lifecycle Cost Estimate	LC	I	
Market Research	EXT	SD	
Master Verification Plan	ITP	I	F
NAS Architecture	ITP	SD	
NAS Concept of Operations	FA	SD	
NAS System Engineering Management Plan	MSE	SD	
Operational Concept Demonstrations	S	SD	SD
Operational Services and Environmental Description	FA	I	F
Physical Architecture	S	C	SD
Planning Criteria	ALL except ITP		SD
Program Risk Register	RSK		SD
Program Risk Summary	RSK	SD	SD
Requirements[2]	RM	I	F
Risk Mitigation Plan Summary	RSK	SD	SD
Risk Mitigation Plans	RSK	SD	SD
Stakeholder Needs	EXT	F	SD
Statement of Work[1]	EXT		I
Standards	EXT	SD	
System Engineering Management Plan	ITP	I	F
Technology	EXT	SD	
Tools/Analysis Requirements	ALL except EXT, ITP, IM, IA, CM, & Val	SD	SD
Trade Study Report	TS	SD	SD
Validation Reports	Val	SD	SD
Verification Criteria	SpecEng	SD	SD
Verification Requirements Traceability Matrix[2]	RM	I	F
Work Breakdown Structure	EXT	F	

1. This work product is not an output of SE per se, but it is identified in order to provide context for the level of SE input to its development.

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
2. This does not imply that there is no further decomposition (e.g., “Final” requirements at this point in time is with respect to the Final Requirements Document (fRD), yet further decomposition takes place to generate a specification). NOTE: See Table 3.3-1 for legend.			

3.3.2.3.3 Final Investment Analysis Pre-Initial System Requirements Review Entrance Criteria

These criteria include the following:

- Work products from the initial IA stage have been completed
- Required disciplines have been identified
- Trade Studies (Section 4.6) have been planned
- Initial baseline planning has been completed
- The initial IA decision (JRC 2A) has been made, authorizing the program to proceed to the final IA stage

3.3.2.3.4 Final Investment Analysis Pre-Initial System Requirements Review Exit Criteria

These criteria include the following:

- All work products identified as final IA pre-ISRR outputs have been completed to the version level specified
- The ISSR has been successfully completed if conducted
- All remaining concepts performance requirements have been attained

3.3.2.3.5 System Engineering Element Tasks

As in previous phases of SE efforts—in addition to the tasks identified below— each SE Element active during this phase shall surface concerns/issues that present risk to the program, as well as any constraints that bound future Trade Studies (Section 4.6). Furthermore, those active SE Elements that involve analysis shall develop their requirements for analysis (e.g., necessary tools, required analyst levels of competencies).

3.3.2.3.5.1 Tasks for the Integrated Technical Planning Element

The level of Integrated Technical Planning (Section 4.2) increases during this stage. The following plans are finalized:

- IPP
- MVP
- SEMP

- Integrated Lifecycle Plan

3.3.2.3.5.2 Tasks for the Requirements Management Element

At this stage during Requirements Management (Section 4.3), the fRD is created in preparation for the ISRR, and the final draft of the fRD VRTM is developed for further population during the Verification process (Section 4.12). Additional activities include continued requirements database development and initial specification work.

3.3.2.3.5.3 Tasks for the Functional Analysis Element

Functional Analysis's (Section 4.4) primary task is to move to the next level of functional decomposition to identify the next lower-level functional requirements. Lower-level FFDs are created to document this decomposition. FFDs define the approved sequence of functions that the subsystems perform and lower-levels of the hierarchy to satisfy the overall needs. The functional architecture is a link to the Requirements Management process (Section 4.3) and the Synthesis process (Section 4.5). The functional architecture at this level is documented via FFDs, system behavior diagrams, system timelines, and/or via other Functional Analysis tools and techniques deemed appropriate by the program. Eventually, post ISRR, the completed Functional Analysis for the selected concept is provided as input to the APB document. In addition, the OSED is finalized.

3.3.2.3.5.4 Tasks for the Synthesis Element

The physical architecture of the selected alternative is further decomposed. During this process, design constraints are identified and used to bound further Trade Studies and Lifecycle Engineering efforts.

3.3.2.3.5.5 Tasks for the Trade Studies Element

Trade Studies (Section 4.6) is an organized decisionmaking process to resolve complex questions. As the selected system alternative is further decomposed, Trade Studies shall be conducted to identify the preferred concepts to perform lower-level functions. The results are documented in a trade study report.

3.3.2.3.5.6 Tasks for the Interface Management Element

During Interface Management (Section 4.7), IRDs are finalized, and conceptual drafts of the ICDs are developed. Functional and physical interfaces internal to the system are continually captured via interface control scope sheets as the functional and physical architectures become more detailed.

3.3.2.3.5.7 Tasks for the Specialty Engineering Element

As the concept of the system is further defined, the analyses and demonstrations performed during the Specialty Engineering process (Section 4.8) are used to provide data (i.e., verification criteria) for Synthesis (Section 4.5), Trade Studies (Section 4.6), and Verification (Section 4.12). Specialists examine the proposed solutions to determine which best satisfies the specialty requirements, after which they capture their findings in DARs.

3.3.2.3.5.8 Tasks for the Integrity of Analyses Element

The Integrity of Analyses process (Section 4.9) continues to provide credible analysis results for the latest conducted analyses.

3.3.2.3.5.9 Tasks for the Risk Management Element

Risk Management efforts (Section 4.10) transition to focus on the selected alternative. Risk mitigation plans are developed for all medium- and high-risk items identified for the selected concept. The program risk register is created and updates to the program risk summary, risk mitigation plans, and risk mitigation plan summary are made to filter out risks not associated with the final concept.

3.3.2.3.5.10 Tasks for the Validation and Verification Element

The level of effort for the Validation and Verification process (Section 4.12) is to validate requirements and document validation reports. Verification criteria identified through Specialty Engineering analyses (Section 4.8), along with the existing set of validated requirements, are used to further identify any tools/analysis requirements for eventual Verification activities.

3.3.2.3.5.11 Tasks for the Lifecycle Engineering Element

A final lifecycle cost estimate that is based on the selected alternative is developed in Lifecycle Engineering (Section 4.13). The Integrated Lifecycle Plan is finalized to reflect the maturing program planning and captures planning for real estate, deployment and transition, integrated logistics support, sustainment/technology evolution, and disposal.

3.3.2.3.6 Final Investment Analysis Post-Initial System Requirements Review

Table 3.3-6 summarizes final IA Post-ISRR inputs and outputs.

Table 3.3-6. Final Investment Analysis Post-Initial System Requirements Review Inputs and Outputs

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Acquisition Program Baseline[*]	EXT	I	F
Baselines	CM	SD	SD
Certification Package	SpecEng		I
Concerns/Issues	ALL	SD	SD
Configuration Description	S		I
Constraints	ALL except TS	SD	SD
Corporate Strategy and Goals	EXT	SD	
Credible Analysis Results	IA	SD	SD
Demonstrations	SpecEng	SD	SD
Description of Alternatives	S	F	
Design Analysis Reports	SpecEng	SD	SD
Design Constraint	S	SD	SD
External Environmental Forces	EXT	SD	
FAA Management Decisions	EXT	SD	

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
FAA Policy	EXT	SD	
Functional Architecture	FA	F	SD
Government and International Regulations and Statutes	EXT	SD	
Integrated Lifecycle Plan	ITP	F	SD
Integrated Program Plan	ITP	F	SD
Integrated Program Schedule	EXT	F	
Interface Control Document	IM	C	I
Interface Requirements Documents	IM	F	SD
Legacy System	EXT	SD	
Lifecycle Cost Estimate	LC	I	F
Market Research	EXT	SD	
Master Verification Plan	ITP	F	SD
NAS Architecture	ITP	SD	
NAS Concept of Operations	FA	SD	
NAS System Engineering Management Plan	MSE	SD	
Operational Concept Demonstrations	S	SD	
Operational Services and Environmental Description	FA	F	
Physical Architecture	S	C	I
Planning Criteria	ALL except ITP		SD
Program Risk Register	RSK	SD	SD
Program Risk Summary	RSK	SD	SD
Requirements	RM	F	SD
Risk Mitigation Plan Summary	RSK	SD	SD
Risk Mitigation Plans	RSK	SD	SD
System Engineering Management Plan	ITP	F	
Stakeholder Needs	EXT	SD	
Standards	EXT	SD	
Statement of Work*	EXT	I	F
Technology	EXT	SD	
Tools/Analysis Requirements	ALL except EXT, ITP, IM, IA, CM, & Val	SD	SD
Trade Study Report	TS	SD	SD
Validation Reports	Val	SD	SD
Verification Criteria	SpecEng	SD	SD
Verification Requirements Traceability Matrix	RM	F	SD
Work Breakdown Structure	EXT	SD	

* This work product is not an output of SE per se, but it is identified in order to provide context for the level of SE input to its development.

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
NOTE: See Table 3.3-1 for legend.			

3.3.2.3.7 Final Investment Analysis Post-Initial System Requirements Review Entrance Criteria

These criteria include the following:

- All work products identified as final IA pre-ISRR outputs have been completed to the version level specified
- The ISRR has been successfully completed
- Initial concepts performance requirements have been attained

3.3.2.3.8 Final Investment Analysis Post-Initial System Requirements Review Exit Criteria

These criteria include the following:

- All work products identified as final IA post-ISRR outputs have been completed to the version level specified
- The solution selected at the Initial Investment Analysis Decision is defined via a physical architecture with assurance that it meets all system requirements
- The final IA decision has been made, authorizing the program to continue into the SI phase

3.3.2.3.9 System Engineering Element Tasks

As in previous phases of SE efforts—in addition to the tasks identified below— each SE Element active during this phase shall surface concerns/issues that present risk to the program, as well as any constraints that bound future Trade Studies (Section 4.6). Furthermore, those active SE Elements that involve analysis shall develop their requirements for analysis (e.g., necessary tools, required analyst levels of competencies).

3.3.2.3.9.1 Tasks for the Integrated Technical Planning Element

During Integrated Technical Planning (Section 4.2), plans are maintained and updated as necessary.

3.3.2.3.9.2 Tasks for the Functional Analysis Element

The Functional Analysis process (Section 4.4) continues functional decomposition to the next level of functions and documents via sequenced traceable functional flow diagrams. This resulting functional architecture is the baseline starting point for Functional Analysis activities that will continue during SI.

3.3.2.3.9.3 Tasks for the Requirements Management Element

The Requirements Management process (Section 4.3) is the primary stage during which to update the fRD and VRTM using feedback from the ISRR. Additional activities include continued requirements database development and specification work.

3.3.2.3.9.4 Tasks for the Synthesis Element

The initial draft of the physical architecture for the selected alternative is completed by the end of this stage. Additional design constraints are identified and used to bound further Trade Studies and Lifecycle Engineering efforts, as well as the continued design efforts to take place in the next phase.

3.3.2.3.9.5 Tasks for the Trade Studies Element

The Trade Study process (Section 4.6) continues, as needed, to derive the best solution for the lower-levels of the system.

3.3.2.3.9.6 Tasks for the Interface Management Element

At this stage during Interface Management (Section 4.7), the ICDs are updated to the initial draft. Functional and physical interfaces internal to the system are continually captured via interface control scope sheets as the functional and physical architectures become more detailed.

3.3.2.3.9.7 Tasks for the Specialty Engineering Element

During Specialty Engineering (Section 4.8), additional DARs are developed and used to support the refinement and validation of requirements. Demonstrations may continue to provide data to develop additional verification criteria. The initial draft(s) of certification package(s) for any required certifications are developed.

3.3.2.3.9.8 Tasks for the Integrity of Analyses Element

Credible analysis results are developed and used during Integrity of Analyses (Section 4.9) to ensure that the analyses conducted to support the down-selection decision are viable.

3.3.2.3.9.9 Tasks for the Risk Management Element

Risk Management's (Section 4.10) primary task in this stage is to determine new risks and provide mitigation plans for these risks. This effort supports Synthesis (Section 4.5) and Trade Studies (Section 4.6) efforts. Work products for this element include updates to the program risk register, program risk summary, risk mitigation plans, and risk mitigation plan summary.

3.3.2.3.9.10 Tasks for the Configuration Management Element

Configuration Management's (Section 4.11) primary task during the final IA post ISRR is to bring the baselines, supporting documentation, requirements, and analyses under configuration control.

3.3.2.3.9.11 Tasks for the Validation and Verification Element

The Validation and Verification effort (Section 4.12) is to complete the validation of requirements for the selected alternative and document via validation reports, which are then provided as input to the APB. Verification criteria identified through Specialty Engineering analyses, along with the existing set of validated requirements, are used to further identify any tools/analysis requirements for eventual Verification activities to begin creating the Requirements Verification Compliance Document (RVCD).

3.3.2.3.9.12 Tasks for the Lifecycle Engineering Element

During Lifecycle Engineering (Section 4.13), the lifecycle cost estimate is finalized based on the selected concept. The final set of validated requirements, final DARs, and final trade study reports are used to support this estimate.

3.3.3 Solution Implementation Phase

3.3.3.1 Objectives

The SI phase begins with the final IA decision at JRC 2B—an acquisition program is established for the solution selected at JRC 2A—and ends when the new capability goes into service. The SE activities conducted during SI vary widely, depending on the nature and scope of the acquisition program. For example, the activities associated with buying and deploying a commercial product typically are much less complex and time-consuming than those for a product requiring development. However, in each case, products shall be able to meet stakeholder requirements, be operationally suitable, and be compatible with other operational systems before the decision is made to place it in service. The main objective of this phase is to successfully complete the necessary actions and activities to obtain the solution and to accept a product or service for operational use.

3.3.3.2 System Engineering Activities

SE activities required to accomplish the SI objectives appear in Figure 3.3-4. While the SE activities vary widely, depending on the program, the interactions of the SE processes remain essentially the same as in the IA phase. Up front, the activities involve finalizing and baselining the system, its requirements, and the program to support its development and operation. The SE effort then focuses on transforming the accepted concept into a product for deployment. Thus, toward the beginning of the phase, the emphasis remains on the core SE processes, which continue to refine the requirements and bring greater resolution to the design. In the latter portion of this phase, the emphasis shifts to Verification activities (Section 4.12) to verify that the system has been built and integrated according to the requirements.

The final set of SI activities consists of installing the product or service at each site and certifying it for operational use, as appropriate, which typically includes implementation planning, installation and checkout, integration and shakedown, dual operations, and removal and disposal of obsolete equipment.

Various reviews and audits are conducted throughout the SI phase to maintain proper oversight of system development. These reviews and audits, listed below, are defined in the glossary:

- System Requirements Review (SRR)

- System Design Review (SDR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Verification Readiness Review (VRR)
- Functional Configuration Audit (FCA)
- Physical Configuration Audit (PCA)

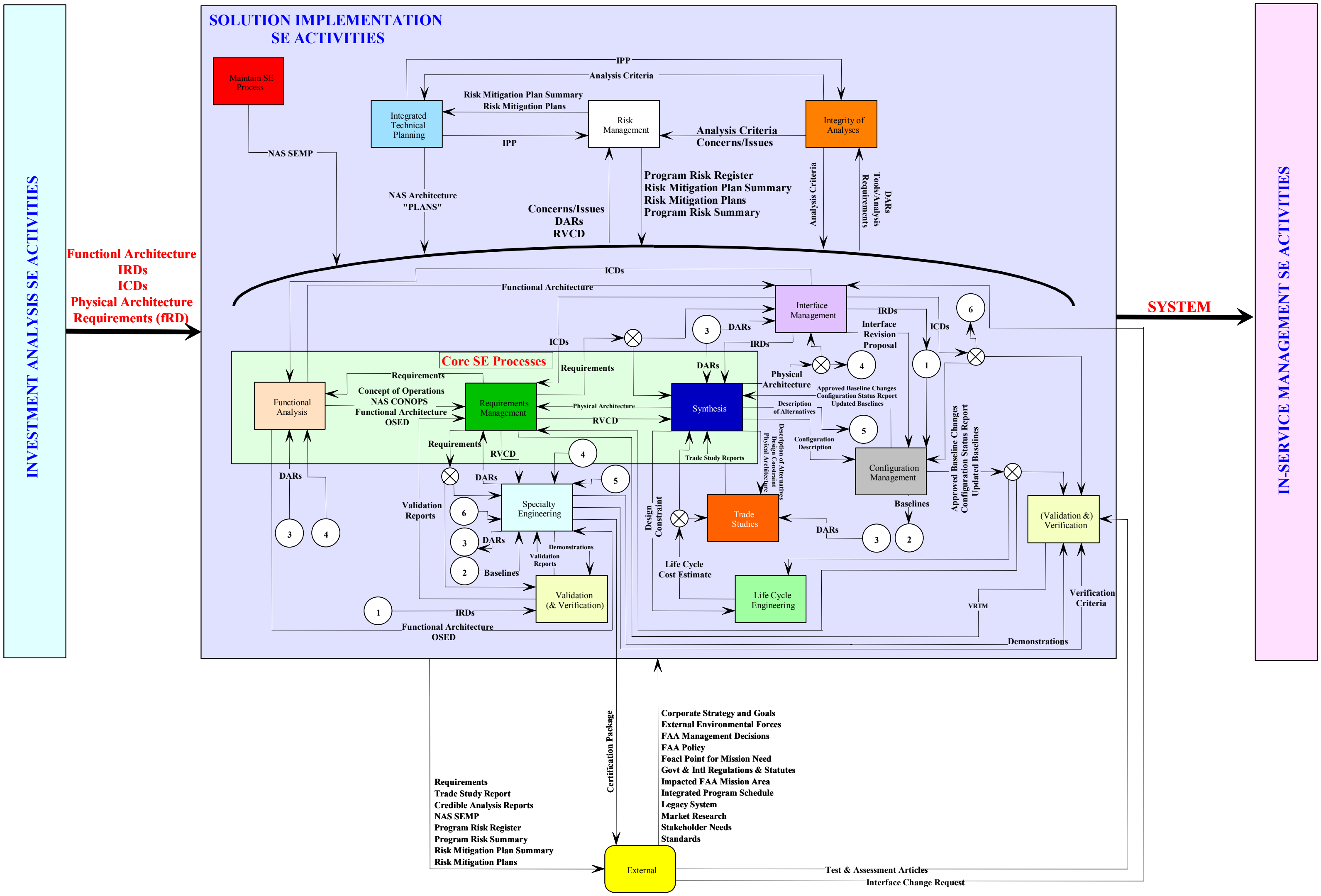


Figure 3.3-4. Solution Implementation System Engineering Activities

Table 3.3-7 summarizes the SI inputs and outputs. All products are completed and finalized before completion of the SI phase(i.e., they are not outputs at the end of the phase or a complete result of this phase's SE efforts; rather, they are produced at various points within the SI phase). Each program shall plan at what point in time during this phase that each product is required. For example, final ICDs shall be in place before development and well established for PDR and CDR.

Table 3.3-7. Solution Implementation System Engineering Inputs and Outputs

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Acquisition Program Baseline	EXT	F	
Approved Baseline Changes	CM		SD
Baselines	CM		SD
Certification Package	SpecEng	I	F
Concerns/Issues	ALL	SD	SD
Configuration Description	S	I	F
Configuration Status Report	CM		SD
Constraints	ALL except TS	SD	SD
Corporate Strategy and Goals	EXT	SD	
Credible Analysis Results	IA	SD	SD
Demonstrations	SpecEng	SD	SD
Design Analysis Reports	SpecEng	SD	SD
Design Constraint	S	SD	SD
External Environmental Forces	EXT	SD	
FAA Management Decisions	EXT	SD	
FAA Policy	EXT	SD	
Functional Architecture	FA	SD	SD
Government and International Regulations and Statutes	EXT	SD	
Integrated Lifecycle Plan	ITP	SD	SD
Integrated Program Plan	ITP	SD	SD
Integrated Program Schedule	EXT	SD	
Interface Change Request	EXT	SD	
Interface Control Documents	IM	I	F
Interface Requirements Document	IM	SD	SD
Interface Revision Proposal	IM		SD
Legacy System	EXT	SD	
Master Verification Plan	ITP	SD	SD
NAS Architecture	ITP	SD	
NAS Concept of Operations	FA	SD	
NAS System Engineering Management Plan	MSE	SD	
Physical Architecture	S	I	F
Planning Criteria	ALL except ITP	SD	SD
Program Risk Register	RSK	SD	SD
Program Risk Summary	RSK	SD	SD

WORK PRODUCT	PRODUCING SE ELEMENT	INPUT	OUTPUT
Requirements	RM	SD	SD
Risk Mitigation Plan Summary	RSK	SD	SD
Risk Mitigation Plans	RSK	SD	SD
Requirements Verification Compliance Document	RM, Verification		F
Stakeholder Needs	EXT	SD	
Standards	EXT	SD	
Statement of Work	EXT	F	
Test and Assessment Articles	EXT	F	
Tools/Analysis Requirements	ALL except IM, CM, & Val	SD	
Trade Study Report	TS	SD	SD
Updated Baselines	CM		SD
Validation Reports	Val	SD	SD
Verification Criteria	SpecEng	SD	SD
Verification Requirements Traceability Matrix	RM, Verification	SD	SD
NOTE: See Table 3.3-1 for legend.			

3.3.3.3 Solution Implementation Phase Entrance Criteria

These criteria include the following:

- The final IA decision (JRC 2B) has been made, authorizing the program to continue into SI
- IA outputs have been completed
- Final APB has been completed (via a process external to SE)

3.3.3.4 Solution Implementation Phase Exit Criterion

This criterion is as follows:

- The In-Service Decision has been made, authorizing the program to deploy and put the developed system into service.

3.3.3.5 System Engineering Element Tasks

As in previous stages of SE efforts—in addition to the tasks identified below— each SE Element active during this phase shall surface concerns/issues that present risk to the program, as well as any constraints that bound future Trade Studies (Section 4.6).

3.3.3.5.1 Tasks for the Integrated Technical Planning Element

During Integrated Technical Planning (Section 4.2), plans are maintained and updated as necessary.

3.3.3.5.2 Tasks for Functional Analysis

Functional Analysis (Section 4.4) continues to decompose functions and develop the functional architecture, which continues as long as requirements are developed.

3.3.3.5.3 Tasks for the Requirements Management Element

At the beginning of the SI phase, the Requirements Management process (Section 4.3) is focused on decomposing and finalizing the system specification. As the phase progresses, the requirements effort involves maintaining traceability from high-level requirements to their decomposed lower-level requirements down to actual verification cases and results, and tracking any deviations or waivers to the requirements set as development and verification progress. The final VRTM and RVCD are received as a result of the Verification process with the RVCD being used by Requirements Management to report out to stakeholders.

3.3.3.5.4 Tasks for the Synthesis Element

The physical architecture of the selected alternative is decomposed and finalized during the Synthesis process (Section 4.5) in an iterative mode, as it is employed to design the system's lower-level components and parts being developed. A resulting configuration description is produced and baselined during this phase.

3.3.3.5.5 Tasks for the Trade Studies Element

The Trade Studies process (Section 4.6) continues, as needed, to derive the best solution for the lower-level components and parts of the system.

3.3.3.5.6 Tasks for the Interface Management Element

Interface Management (Section 4.7) is used to finalize the ICDs and process any Interface Change Requests. Updates to finalized ICDs are processed accordingly via interface revision proposals.

3.3.3.5.7 Tasks for the Specialty Engineering Element

The focus of Specialty Engineering (Section 4.8) during this phase is to conduct the various analyses to support the definition of requirements at all levels; support Validation (Section 4.12) of requirements; support the Verification (Section 4.12) of requirements and/or the certification process (e.g., in the areas of safety and information security), as needed; support Trade Studies (Section 4.6); and assist Risk Management (Section 4.10).

3.3.3.5.8 Tasks for the Integrity of Analyses Element

During Integrity of Analyses (Section 4.9), credible analysis results are generated for analyses completed during the SI phase.

3.3.3.5.9 Tasks for the Risk Management Element

The Risk Management process (Section 4.10) continues with risk mitigation plans being put into effect and developing and documenting new plans as new risks are identified.

3.3.3.5.10 Tasks for the Configuration Management Element

Configuration Management's (Section 4.11) primary task during this phase is to maintain configuration control. Changes to the configuration are considered and, if approved, documented via configuration status reports. Baselines are controlled with updates and approved engineering changes are documented and disseminated.

3.3.3.5.11 Tasks for the Validation and Verification Element

Validation (Section 4.12) of requirements continues as the requirements are decomposed through the various system levels. Validation continues as long as requirements (at any level) are developed. Verification efforts (Section 4.12) increase, especially toward the end of the SI phase. As various levels of verification are conducted on test and assessment articles, the final RVCD and the VRTM are populated with results and fed back to the Requirements Management process (Section 4.3).

3.3.3.5.12 Tasks for the Lifecycle Engineering Element

During the SI phase, Lifecycle Engineering elements are engaged in executing the planning that was finalized during the IA phase. This includes acquiring property, facilities, and the physical infrastructure to house the system; detailing the installation and checkout schedule of activities, including site preparation and onsite personnel support; deploying the system; supporting ISR checklist action resolution; training test, operations, and maintenance personnel; ensuring that documentation and spares are procured, verified, and delivered; performing continuous market research activities on any COTS products to project obsolescence situations and mitigate the risks in support of Risk Management (Section4.10); and conducting the disposal activities that are needed for assets that are to be replaced.

3.3.4 In-Service Management

In-Service Management involves two distinct sets of work activities. The first set monitors and assesses the real-world performance of the system against its requirements and expected benefits in the APB and takes action to optimize performance throughout its operational life. The second set of activities deals with operating and maintaining the system throughout its service life, as well as maintaining the physical and support infrastructure. The various SE elements are employed within both sets of these activities. Regarding this latter set of activities, the results of SE efforts are used to support the decisionmaking process regarding when a new capability or improvement needs to be in place.

In addition to the timing decision, a decision is made regarding whether modifications or improvements are feasible within approved sustainment funding in the APB. If an engineering change to the system within the sustainment funding cannot be supported, then the shortfall is addressed via the standard AMS lifecycle phases; thus, the SE efforts for this route are as noted in "Mission Analysis Phase" (Paragraph 3.3.1), "Investment Analysis Phase" (Paragraph 3.3.2), and "Solution Implementation Phase" (Paragraph 3.3.3).

If the effort to modify and/or optimize system performance is within the scope of sustaining funds, then the various SE elements are employed much as in the SI phase but on a lesser scale. The specific SE process and associated level of effort depend on the scope of the upgrade.

If a modification is made to sustain system operations beyond its planned service life, a new investment decision for a service life extension must be requested. Again, the SE efforts during this phase are essentially the same as noted in "Solution Implementation Phase" with respect to the pieces of the system that are being modified to extend the life of the system as a whole.

3.3.5 Disposal

SE efforts to support disposal of a system being replaced occur during the new system's SI phase. Lifecycle Engineering (Section 4.12) defines the process for planning and executing disposal activities. The Integrated Technical Planning process (Section 4.2) is used to develop a Disposal Plan in accordance with FAA Order 4800.2, Utilization and Disposal of Excess and Surplus Personal Property.

3.4 Reserved

3.5 Reserved

3.6 Guidance for Tailoring of System Engineering

This section provides guidance regarding the conduct of SE on programs that do not include all engineering disciplines or have unique programmatic demands. The following principles are not intended to be comprehensive, but rather to give general guidelines that may be applied to any part of SE and to programs of any size if rationalization is provided.

3.6.1 Basic Principle of Tailoring of System Engineering

The basic principle in program tailoring of SE is that for programs that alter the NAS, reduction in size of an individual element is permissible, but deletion is not. This principle does not mean that large, complex programs may be de-scoped, except under the ground rules listed in this section. The following paragraphs give examples of specific aspects of SE and how they shall be treated in a tailoring effort.

3.6.2 Tailoring of Acquisition Management System Process Phase Aspects of System Engineering

"Relationship of the System Engineering Processes to the Acquisition Management System Program Lifecycle" (Section 3.2) describes the AMS phases employed on all programs. These phases shall not be eliminated or combined on any program; however, they may be shorter in duration. Furthermore, the entrance and exit criteria for any phase shall not be ignored. In addition, the exit reviews associated with the phases shall not be eliminated. "Tailoring of Review Aspects of System Engineering" (Paragraph 3.6.5) discusses the reviews.

3.6.3 Tailoring of Planning Aspects of System Engineering

All plans pertinent to the program shall be written; however, some plans may be shortened to a single page. The most important plan is the IPP (Integrated Technical Planning (Section 4.2)). The IPP may be reduced to its essential elements, and individual entries may be as short as a single line. The aspects that shall be retained are:

- AMS Phases (Section 3.2)
- SE elements (Sections 4.2 through 4.14)
- SE specialties to be employed on the program

The IPP shall capture information that shows the phase of each SE process, where each engineering specialty is employed, and what work product each process produces. This information is required to produce a forecast of program effort and meaningful schedule.

3.6.4 Tailoring of System Engineering Element Aspects of System Engineering

Sections 4.2 through 4.14 describe the 13 SE elements. Each SE process shall be performed on all programs that change the NAS, regardless of the scope of the program, while the nature of the program determines the depth to which each process is performed.

3.6.5 Tailoring of Review Aspects of System Engineering

Two rules prevail regarding this topic: (1) all major reviews shall be performed at the end of the phases defined in "Relationship of the System Engineering Processes to the Acquisition Management System Program Lifecycle" (Section 3.2); and (2) reviews shall not be combined. However, a review may be shortened to an hour for a simple project. The moderator of the review shall confirm the basic purpose and ground rules of the review to ensure that they have not been compromised. Software reviews are only required if software is selected as a solution to the system requirements ("Tailoring of Software Aspects of System Engineering" (Paragraph 3.6.10)).

3.6.6 Tailoring of Functional Analysis Aspects of System Engineering

The Functional Analysis process (Section 4.4) is an example of a fundamental process whose basic principles shall be maintained on programs of any size. On all programs, Functional Analysis shall be used to derive requirements in a structured and systematic method. The depth, scope, and tools used in the development of the functional architecture may be tailored according to program complexity.

3.6.7 Tailoring of Requirements Management Aspects of System Engineering

The Requirements Management process (Section 4.3) is an example of a fundamental process whose basic principles shall be maintained on programs of any size. On all programs, a Requirements Management tool shall be used and the results loaded into the master requirements database.

3.6.8 Tailoring of Programmatic Risk Management Aspects of System Engineering

The Risk Management process (Section 4.10) shall be performed on programs of any size and throughout the lifecycle. The example forms provided in Risk Management show that risk to the process is not paper intensive. On the contrary, the Risk Management process presented is extremely practical and adaptable to programs of any size.

3.6.9 Tailoring of Verification Aspects of System Engineering

The Verification process (Section 4.12) is one of the SE basic principles—all requirements shall be verified, which is not to say that extensive testing is required, but simply that steps shall be taken to ensure that the solution satisfies the requirements. A simple analysis often provides that assurance. This principle shall not be compromised on small programs. Failure to verify requirements may cause small programs to turn unintentionally into large programs.

3.6.10 Tailoring of Software Aspects of System Engineering

Software is a solution to system (i.e., hardware and software) requirements. Hence, if software is not selected as a solution, software reviews and other documentation are not required. If software is required, standard software reviews and documentation are required. However, it shall not be assumed that, if a program is designated as a software program, then the total system aspects of SE may be ignored.

3.6.11 Tailoring of Lifecycle Engineering Aspects of System Engineering

Reserved